FIELD GUIDE

GEOLOGIC FEATURES OF THE SAN ANDREAS FAULT ZONE FROM FORT TEJON STATE PARK TO PALLET CREEK

SPONSORED BY

U.S.D.I. BUREAU OF LAND MANAGEMENT
BAKERSFIELD DISTRICT OFFICE

March 6, 1993

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FIELD TRIP LEADERS

Gregg Wilkerson, Geologist
Anne Falcon, Geologist
Phil Lopez, Soil, Water, and Air
Frank Mesa, Assistant Technician

CONTRIBUTORS

Danny Conway, Lake Hughes Community Club
Devil's Punchbowl L. A. County Park
Fort Tejon State Park
Charles Foss, Geologist
National Cement Company
Southern California Edison
and other BLM personnel and volunteers

THE SAN ANDREAS FAULT: FORT TEJON STATE PARK TO PALLET CREEK

This field trip is one of a series of geologic excursions offered to the general public by the Bureau of Land Management in order to increase awareness and appreciation of the geology, mineral resources, and geologic hazards of southern California. For copies of this field guide, for additional information on college credit offered through the California State University-Bakersfield, and/or to be placed on a mailing list for future geologic excursions write:

Bureau of Land Management
800 Truxtun Avenue, Rm. 311
Bakersfield, CA 93301
(805) 861-4210

OVERVIEW

The trip starts from Fort Tejon State Park parking lot, located on the west side of I-5, north of Gorman, south of Bakersfield, in the town of Fort Tejon, the headquarters of the Tejon Ranch. From Fort Tejon, the tour will proceed along the San Andreas Fault through Gorman, the National Cement Company, Lake Hughes lunch stop, Palmdale, Devil's Punchbowl, and ends at Pallet Creek.

In order to present the maximum amount of information, most stops are limited to 20 minutes, except for the lunchtime stop and the National Cement stop which will be longer. Participants are encouraged to bring a sack lunch and beverages. All vehicles are encouraged to bring a CB radio set to channel 20.

A CB RADIO OR HIGH-CLEARANCE VEHICLE IS NOT A REQUIREMENT FOR THIS TRIP. ALL TRAVEL IS ON PAVED ROADS.

FIELD STOPS

STOP # 1. Fort Tejon State Park

STOP # 2. Overlook of the San Andreas and Garlock Fault intersection

STOP # 3. National Cement mine and plant

LUNCHSTOP AT LAKE HUGHES COMMUNITY CLUB

STOP # 4. Roadcut at State Highway 14 & Avenue S in Palmdale

STOP # 5. Devil's Punchbowl Los Angeles County Park

STOP # 6. Pallett Creek site

FIGURES

FIGURE # 1. Truncated river terrace and alluvial fan near intersection of San Andreas and Garlock Faults.

FIGURE # 2. Example of accelerated erosional processes in road cut near Gorman along the San Andreas Fault.

FIGURE # 3. Soil and vegetation contrasts at along San Andreas Fault. Neenach Formation to right. Quartz Monzonite to left.

FIGURE # 4. Truncated Hillside.

FIGURE # 5. Truncated Hillside.

FIGURE # 6. Lake Hughes, a sag pond along the San Andreas Fault Zone.

FIGURE # 7. Deformed Hungry Valley Formation in pressure ridge within San Andreas Fault zone at Highway 14 roadcut near Palmdale.

FIGURE # 8. Punchbowl Formation rocks at Devil's Punchbowl County Park.

TABLES

MAPS

Maps of the route from Fort Tejon to Pallett Creek. These are all shown on U.S. Geological Survey Topographic map bases.

ROAD LOG

MILEAGE	DESCRIPTION
0.0	**START.** From the east exit of the library parking lot turn left (north) and immediately turn right (east) onto Truxtun Avenue. Stay in the right lane. Turn right (south) onto Union Avenue.
	Turn right (west) onto State Highway 58.
2.8	Turn south from the right lane (south to Los Angeles) onto State Highway 99.
7.5	Panama Lane.
9.5	Taft Highway. State Highway 119.

San Joaquin Valley

The southern San Joaquin Valley beneath us was once a vast inland sea. The basin of this ancient seaway was bounded on the east by ancestral Sierra Nevada Mountains and on the west by ancestral coast ranges. The rising mountains eroded material into the sinking basin. This great basin now holds, in some places, over 30,000 feet (9150 meters) of sediments from the mountains.

General Geologic Principles

Geologists that study sequences of rock strata are called stratigraphers. The science is based on two principles identified in 1669 by Nicholas Steno, an Italian physician. The principles are called the Principle of Original Horizontality and the Principle of Superposition. The first principle states that rock layers are originally laid down in a horizontal position. The second principle states that in an undisturbed sequence of rocks, the oldest are on the bottom and the youngest are on top. Using this science, stratigraphers have identified many mappable rock layers in the Southern San Joaquin Valley and other regions.

By correlating rock layers of similar type and age around the world, geologists have built up the "Geologic Column" (See Table 1), a generalization about the age relationships of rocks of the earth's crust. Geologists have found that each rock layer has an unique assemblages of fossils. In general, older fossils are smaller and simpler, younger fossils appear more like modern living forms and generally are more complex. By studying the fossils, determinations can be made where a rock layer would fit into the Geologic Column. In this way, relative ages for the sequence rocks can be determined. On the field trips, the names used for past geologic ages can be found in the Geologic Column (see Table 1). The numerical (absolute") ages for the geologic column are determined most often by the analysis of the steady decay or breakdown of radioactive minerals in the rocks.

GEOLOGICAL TIME SCALE
(In use by the U. S. Geological Survey)

Era or Erathem	System or Period	Series (Epoch)	Age Estimates (boundary in millions of years ago)	Outstanding Events in Physical History and Living History
		Holocene		Several Glacial Ages, Homo Sapiens
	Quaternary	Pleistocene		Great Lakes, Missouri and Ohio Rivers
			1.8	
		Pliocene		Later Hominids
			5.0	
		Miocene		Colorado River, Primitive Hominids
			22.5	
Cenozoic	Tertiary	Oligocene		Basins and Ranges, Nevada, grasses, grazing mammals
			37.5	
		Eocene		Volcanic Activity, Yellowstone, primitive horses
			53.5	
		Paleocene		Rocky Mountains, spreading of mammals
			65.0	Dinosaur extinction
	Cretaceous			Lower Mississippi River, flowering plants
			136.0	Climax of dinosaurs
Mesozoic	Jurassic			Birds
			190-195.0	
	Triassic			Atlantic Ocean, conifers, cycads, primitive mammals
			225.0	
	Permian			Climax of making of Appalachian Mountains, Mammal-like reptiles
			280.0	
	Pennsylvanian			Coal forests, insects, amphibians, reptiles
			320.0	
	Mississippian			
			345.0	
Paleozoic	Devonian			Earliest economic coal deposits, amphibians
			395.0	
	Silurian			Land plants and land animals
			430-440.0	
	Ordovician			Beginning of making of Appalachian Mountains, Primitive fishes
			500.0	
	Cambrian			Earliest oil and gas fields, marine animals abundant
			570.0	
Precambrian				Oldest dated rocks, primitive marine animals, green algae, bacteria, blue-green algae

TABLE # 1. Geological Time Chart. U. S. Geological Survey.

17.5 Herring Road.

21.5 Copus Road/David Road.

22.9 Mettler.

23.0 The Superior-Tenneco Sand Hills # 4 oil well was drilled one mile due east in 1975 to a total depth of 22,711 feet (6922 meters), bottoming in the Lower Miocene Temblor Formation. The Mid-Miocene Stevens Sand, an important clastic unit which produces oil at Elk Hills, was encountered at 15,000 feet (4572 meters). The Stevens Sand is productive in the Rio Viejo Field eight miles west of the oil well. The Sand Hills # 4 is one of deepest wells drilled in the Southern San Joaquin Valley.

24.1 Maricopa Highway. State Highway 166.

25.1 The ridge to the north of the Grapevine/California Aqueduct and west of I-5 is Wheeler Ridge. Wheeler Ridge is a completely faulted anticline (an anticline is a fold that is convex upward, whose core contains the stratigraphically older rocks). The anticline is growing eastward toward the freeway as shown by closely dated Holocene terraces.

The wind gap where the California Aqueduct System crosses Wheeler Ridge above the valley floor was originally a streambed. Decreased rainfall and tectonic action forced the ridge to rise faster than the stream eroded, thereby creating a gap in the ridgeline.

Along the northern border of Wheeler Ridge is the White Wolf Fault. This Fault has displaced basin sediments vertically at least 10,000 feet. This fault is an oblique fault with both left-lateral strike-slip and reverse fault motion. The fault maybe a strike-slip fault which has been folded so that recent motion appears reverse. Folding of faults is common in Southern California due to changes in plate motion. A new fold is developing in the alluvial fans, more or less parallel to the older belts of deformation Pleito Thrust and White Wolf Faults, 1.8 miles (3 kilometers) north of the Wheeler Ridge,

In 1952, the Tehachapi-Arvin 7.6-7.7 magnitude earthquake along the White Wolf Fault showed displacement in several places including the area around Wheeler Ridge. Detailed surface mapping of the ruptures led to the discovery of the Southeast oil pool of the Wheeler Ridge Oil Field in 1961. Various pools of the Wheeler Ridge Oilfield are located north and south of the ridge.

The Kern Rock Aggregate operates an assorted rock size

operation at the base of Wheeler Ridge. The company pays a royalty to the oil company to mine the rocks. A few hundred feet north of this operation is the White Wolf Fault.

The site of the new city of San Emigdio is to be located north and south of Wheeler Ridge.

27.3 Interstate 5.

28.4 This is about the location where the White Wolf Fault crosses the highway. Directly ahead is the "Grapevine", named in the 1800's for the grapevines found along a fault associated with the springs in the canyon.

29.4 Lavel Road.

34.0 To the west of "Grapevine Canyon" is an unnamed conglomerate--a sedimentary rock composed of boulders and cobbles, which grades into the San Joaquin Valley sediments. Above the unnamed conglomerate are the older marine sands, silts and shales of the late Oligocene-early Miocene Tecuya Formation. The beds are in reverse order (oldest on top) because the entire sequence of sedimentary rocks in this area have been thrust northward and overturned by the low angle, south-dipping Pleito Thrust Fault.

The Pleito Thrust Fault located at the base of the "Grapevine" and the San Emigdio Mountains to the west is approximately 30 miles (48 kilometers) long and is the result of compression from the south direction due to the San Andreas Fault presence.

To the east of "Grapevine Canyon" is a massive landslide or slope failure. Because of water action, steep slopes, seismicity, and active uplift of this area, landslides deposits are numerous, particularly on the north-facing slopes of the upper plate of the Plieto Thrust Fault.

38.5 STOP #1. FORT TEJON STATE PARK.
/0.0

Fort Tejon

Fort Tejon was an army outpost from 1854 to 1864. The fort's purpose was to protect the Indians and government property in the southern San Joaquin Valley and the San Sebastian Indian Reservation, located 17 miles (27 kilometers) to the north near Arvin, from gold miners. Because of the summer heat, swamps, and mosquitoes, the fort, originally to be located on the valley floor, was built at higher elevations in the mountains near a water source, as the climate was healthier and cooler.

Fort Tejon was headquarters was the home of the First U. S. Dragoons. The fort represented law and order. The various fort activities took the soldiers as far east as the Colorado River and occasionally to Salt Lake City, north in to the San Joaquin Valley and the Owens Valley, and south to Los Angeles. The fort is famous for three things: camels, Peter LeBec tree, and the 1857 earthquake.

Camels

In the 1850's under the direction of the Secretary of War, Jefferson Davis, the U. S. Army Camel Corps was established at Fort Tejon. A total of 28 camels were imported and brought overland from San Antonio, Texas in the fall of 1857. The camel experiment was completely successful. The problem was the reluctance of the Army's muleskinners to care for the camels. With the change in administration and the Civil War in 1861, the camels were removed to Los Angeles and sold to private owners. The government retained the bones of one animal killed by its mate, preserved in the Smithsonian Institution.

Peter LeBec Tree

The town of Lebec was named after an inscription found in 1853 carved on an oak tree in the corner of the parade ground of Fort Tejon. The inscription read "Peter LeBeck, killed by a X [that is, grizzly] bear, October 17, 1837". Little is known of the origin of the man. In 1890, the remains of LeBeck were recovered near the base of the tree, and 25-years later, a French 5-franc coin dated 1837 was found at the site.

1857 Earthquake

On January 9, 1857, within a few days after the completion of the fort's first buildings, the newly constructed buildings were cracked or destroyed by a major earthquake occurring along the northwest trending right-lateral San Andreas Fault. The epicenter is estimated to be about 6 miles (9.6 kilometers) to the southeast (near the area of Three Points). The estimated Richter scale magnitude of 8.0 +/-0.5? of the quake is greater than the 1906 San Francisco earthquake and has been the strongest earthquake to hit southern California in recorded history. Right lateral offset was measured at 30 feet (9 meters). Ground breakage was over 200 miles (320 kilometers) in length.

The ground motion was felt from San Diego to Sacramento. Waters from the Los Angeles River and the Tulare Lake went over their banks. On the coast, Santa Barbara and San Buenaventura Missions were severely damaged. According to one source, a circular sheep corral astride the fault in eastern San Luis Obispo County was broken across the middle and converted to an open S-shaped figure. Fortunately, the only victims were a woman near Fort Tejon who died

when an adobe building collapsed and fell on her and reportedly a cow that fell into a trench opened and reclosed by the earthquake.

The formations beneath the fort in Grapevine Canyon consist of stream alluvium over bedrock. The alluvium depth is greatest on the east and decreases gradually to the west. In 1857 as was common, all the fort structures were constructed of un-reenforced adobe bricks. The closer the structure was to the east side of the valley and the greater the alluvium depth, the more severely the structure was damaged. Major injuries were averted at the fort as half of the company stationed at the fort was on patrol and the other half was outside the fort structures.

Geology of the Area

East of Fort Tejon are the Tehachapi Mountains composed similarly to the Sierra Nevada granites with the late Paleozoic or Mesozoic sedimentary record well exposed (See STOP # 3). The east-west trend of the Tehachapi Mountain block seems to reflect left-slip movement of the Garlock Fault. The granitic formations observed on this field trip represent molten rock bodies several miles in diameter which cooled slowly (86 to 212°F (30-100°C) per million years) and formed coarse-grained igneous rocks. The word igneous comes from the Sanskrit word "agni" meaning god of fire. Sanskrit is the basis of the Indo-European languages, i.e. Celtic, Germanic, Greek, Latin, etc.).

When the granitics intrude from below into older rocks, which may have been sedimentary, igneous, or even older metamorphic rocks, the older rocks are heated and changed into a metamorphic rock mass called a "roof pendants". The greatest degree of baking or metamorphism is directly next to the intrusives. Portions of roof pendants maybe essentially unchanged if positioned far enough away from the granitic contact. An example of "roof pendants" to be seen closeup today is at STOP # 3, National Cement Company.

West of Fort Tejon are the San Emigdio Mountains. The San Emigdio Mountains are associated lower and middle Tertiary units in a east-west trending homocline dipping northward off a pre-Tertiary igneous basement complex. Much of the elevation and northward horizontal growth of the San Emigdio Mountains has been during the past 2 to 4 million years. The rate of change in elevation has been 6 to 12 feet (2 to 4 meters) per 1000 years and northward growth has been 17 to 33 feet (5 to 10 meters) per 1000 years.

SET ODOMETER TO 0.0.

/0.0 Return to I-5, drive south towards Los Angeles.

0.8 Pastoria Fault zone is on left (east) in the drainage valley. This zone is traced for a length of 21 miles (10.6 kilometers) and contains fragments of older metasedimentary rock

(hornfels-a dark aphanitic metamorphic rock) and two separate granitic formations, the Cretaceous Lebec Quartz Monzonite and the School Canyon Granite.

Figure 1. Dissected river terrace and alluvial fan near the San Andreas and Garlock Fault. San Andreas is at base of erosional scarp. Dark rocks are alluvium. Light rocks are Miocene marine sediments.

3.1 Garlock Fault, north of the Lebec turnoff where I-5 veers to the right (west) is an east-west trending left-lateral strike-slip fault. North of the Garlock Fault in this area, is the Cretaceous Lebec Quartz Monzonite. To the south and in the fault contact is a different granitic formation, Tejon Lookout Granite.

3.2 A dissected (cut in half) alluvial fan is directly ahead. A contact between Quaternary alluvium and underlying Tertiary marine rocks is exposed in the dissected fan. The San Andreas is located at the base of the fan (Figure 1).

3.8 Hornfels make up most of the formations to the right (west) of I-5 along the base of mountains at the rest stop.

4.8 Exit I-5 at the Frazier Park off-ramp. The San Andreas Fault is on the other side of the low hills. Turn right (west) onto Frazier Mountain Road towards the town of Frazier Park.

5.4 Cretaceous Lebec Quartz Monzonite is on the right (north).

6.7 At the U.S. Forest Service sign, turn left onto a dirt road that runs west for a few hundred feet and then turn left through the gate.

6.8 After crossing the gate, turn left and follow the road back to the east and then away from the fence.

7.1 Road veers left (southeast) a "Y" intersection entering the zone of tectonic landforms.

7.4 Stay to the left as the road climbs the pressure ridge.

7.6 Proceed towards the power lines to the east. Park under the power lines.

7.7 **STOP #2. OVERLOOK OF THE SAN ANDREAS AND GARLOCK FAULT INTERSECTION.**

San Andreas System

The San Andreas Fault Zone has a total length of 740 miles (1200 kilometers) of which over 600 miles (960 kilometers) are located in western California. The fault extends south from Shelter Cove in Humboldt County, through Daly City, the Coast Ranges, the Carrizo Plain, around the "Big Bend" at Frazier Mountain, through to the Salton Sea in the southeastern part of the state, and on into the Gulf of California. Consisting of a series of parallel faults, the zone is from several hundred yards to a few miles wide. The San Andreas is classified as a right lateral strike slip fault. No matter which side of the fault a person is facing, the fault's motion is to the right.

History

Before the advent of the San Andreas Fault system, the North American Plate and the Farallon-Pacific Plates were adjacent to each other. (The remnant of the Farallon Plate, now called the Gorda-Juan de Fuca Plate, is located off the coast of Oregon-Washington.) The plates formed continental lithosphere at mid-ocean ridges with the subduction of the Farallon Plate occurring beneath the North American Plate. As the subducted crust descended beneath the trench, pieces of the crust became attached to the accretionary forearc slope basin (Franciscan Melange). The remnant forearc basin is the Great Valley sequence. The eroded arc massif (root zone of the former volcanic arc) is the Sierra Nevada batholith.

As the subduction of the Farallon Plate occurred faster than the continental lithosphere was created, the Farallon-Pacific Plates spreading center was swallowed by its own trench. The subduction

of the spreading zone began at the Mendocino Triple Junction, then located near Los Angeles. The junction has since migrated to the north as more of the spreading center was subducted. The transform strike-slip San Andreas Fault is the boundary of the former spreading center-trench system.

In the early 1890's a geologist, Andrew Lawson, sailed from Los Angeles to San Francisco. By observing the linear nature of the coastline, he arrived at the conclusion that faulting was a major structural feature within the state. In 1895, Lawson applied the name, San Andreas, to a recognized fault zone containing San Andreas Lake located south of San Francisco. Within the state, other names were used for various other segments of this same fault. Not until after the 1906 San Francisco earthquake was the San Andreas Fault recognized as a continuous regional structure of major importance and the name was applied to the entire zone. The mismatch of adjacent sides of the San Andreas Fault was thought to be because of vertical displacement. Horizontal displacement was calculated to be from 1 mile (1.6 kilometers) to 25 miles (40 kilometers).

Geologists, Mason Hill and Thomas Dibblee, in 1953, proposed a controversial hypothesis based on matching similar rock types, fossils, and structures of the two opposing plate sides. The new hypothesis was that the San Andreas (this included movement along all the pre-San Andreas Faults-Elsinore, San Jacinto, San Gabriel, and Sur-Nacimiento) has experienced horizontal displacement of 350 miles (560 kilometers) with little vertical displacement.

For example, the Miocene Pinnacles Volcanics Formation has been displaced to the northwest horizontally along the San Andreas 197 miles (315 kilometers) from the chemically and structurally compatible Miocene Neenach Volcanics Formation. Another example of displacement is the Salinian Block adjacent to the west. Before displacement the "exotic" Salinian block was attached to the mainland of Mexico, but because of the forces of the San Andreas and time was detached and migrated northwestward.

In the early 1960's, a new theory was advanced, which further explained Hill and Dibblee's concepts. The new theory was that midoceanic ridges similar to the Atlantic ridge with spreading zones are the places where magmas rise from the mantle and spread laterally to produce new oceanic/continental crust. Eventually the crust is subducted into trenches located at plate boundaries. In the absence of a trench, a transform fault forms the boundary between two plates. The San Andreas is a transform fault and a shear boundary between the northwest moving Pacific Plate and the American Plate. (A transform fault is defined as a strike-slip fault that describes the relative motion of two plates slipping past one another.)

"Big Bend" Structure

The intersection of the Garlock, Big Pine, San Gabriel, and the San Andreas Faults has been described as the "Big Bend" or structural knot of southern California. The origin of the Big Bend has been related to left slip on the Big Pine and Garlock Faults and to movement on the Frazier Mountain thrust and related faults.

Frazier Mountain Thrust

The Frazier thrust is a short thrust fault that dips north and northwest beneath Frazier Mountain. Frazier Mountain is interpreted as a mountain without roots--a squeeze-up block of previously buried PreCambrian banded gneiss that has been thrusted into a high, small massif that cuts across folded much younger Pleistocene nonmarine sedimentary rocks. The block is a splinter that rose up and out from the San Andreas Fault zone and has been rotated 90°.

Garlock Fault

Northwest of this ridge is the Garlock Fault-San Andreas intersection. The Garlock intersects from the east through the large valley with the sag pond, Castaic Lake. Since the 1952 Tehachapi-Arvin earthquake along the White Wolf Fault, the water in this sag pond has been poisoned with selenium. The Garlock Fault extends to the east from the San Andreas Fault to Death Valley, a distance of 150 miles (240 kilometers). The fault is a left lateral vertical fault with a total of 40 miles (64 kilometers) of displacement. Quaternary displacement is estimated to be at least 11 miles (18 kilometers).

Big Pine Fault

About 6 miles (9.6 kilometers) to the west at Lockwood Valley is the Big Pine-San Andreas intersection. The Big Pine Fault is a left-slip fault extending about 50 miles (80 kilometers) to the west. As both the Garlock and the Big Pine show left slip, the unproven theory is that the Big Pine and Garlock Faults were at one time the same system. If so, the faults would have to be subordinate to and younger than the San Andreas to account for the small offset along the San Andreas of 6 miles (9.6 kilometers) between the Garlock and the Big Pine.

Because of ground breakage was reported within Lockwood Valley shortly after an earthquake in 1852, the earthquake was attributed to the Big Pine. Measurements have been made of quaternary horizontal stream offsets up to 3,000 feet (900 meters) and one fan is estimated to have been offset about 1 mile (1.6 kilometers). Since the Miocene time total displacement is measured from 4 to 10 miles (6.5 to 16 kilometers). Evidence indicates that much of the slip of the Big Pine occurred before Miocene time.

San Gabriel Fault

The San Gabriel Fault, considered part of the San Andreas Fault, is about 90 miles (144 kilometers) long extending from Frazier Mountain to north of Mount Wilson. During the last twelve million years, the fault has experienced 40 miles (60 kilometers) of right slip horizontal displacement and vertical displacement along the Ridge Basin of 14,000 feet (4250 meters). The fault has been inactive in the northern segment in quaternary time.

Geomorphology of the Area

From this ridge, a close view of a number of tectonic landforms can be viewed <u>en echelon</u> pressure ridges and faults, diverted drainage, and a sag pond. En echelon is French meaning "in step like arrangement". En echelon ridges are overlapping or staggered arranged ridges. Each ridge is short, but collectively forms a linear zone in which the strike of the individual features is oblique to that of the zone as a whole (Davis, 1982). A sag pond is a small body of water occupying a depression or sag formed where active or recent fault movement has impounded drainage.

The San Andreas Fault is located to the south at the base of the first ridge. A sag pond is situated between the right-stepping <u>en echelon</u> faults. The pressure ridges are also to the south and west. Pressure ridges are tectonic ridges with steep sloped ridges pushed up along the several smaller faults within the larger San Andreas Fault zone. To the west on the south side of Frazier Mountain Road is the remains of a large landslide.

Width of the zone of tectonic landform is as much as 0.8 miles (0.5 kilometer) in width. The tectonic ridges rise up 98 feet (30 meters) high. Within the zone of tectonic landforms is a much narrower zone of recent displacement which includes surface rupture associated with the 1857 Fort Tejon earthquake.

Earthquake Prediction

"When will an earthquake occur again?", is the most commonly asked question about the San Andreas. Fault segments have different rates of movement and earthquake magnitude dependent upon the structure and rock types the fault bisects.

During the past 50 years, repeated surveys have been made across the portion of the San Andreas affected in 1857. The surveys have revealed no sign of creep, nor have any earthquakes been attributed to this segment since 1857--apart from one in 1916. This part of the San Andreas is frequently cited as locked into position by its bend ("Big Bend") into the Transverse Ranges--while strain energy accumulates for the next all-but inevitable strong earthquake.

The Cajun Pass to Maricopa (around the "Big Bend") segment measures no creep and has 7.5 to 8 magnitude earthquakes every 130 to 185 years (calculated over a 1000 years) with 26 to 39-foot (8 to 12 meters) displacement. Since the last earthquake in 1857, an estimated 24 feet (7.2 meters) of strain has accumulated in this area.

North of this location, in a straighter part of the fault near Parkfield, earthquakes occur in the magnitude of 6 every 20 to 32 years (1966 Parkfield). Creep is measured at the rate of inches 0.6 inches (1.5 centimeters) a year.

The segment of the fault from north of Parkfield through Bitterwater Valley-Pinnacles to Hollister is called the creeping segment. The fault is characterized by creep measurements of 1.3 inches (3.3 centimeters) per year and mild earthquakes never greater than an magnitude of 5 (1993 Gilroy). Measurements taken at Bitterwater Valley measure the creep at 1.3 inches (3.3 centimeters) per year with the creep measurement decreasing to 0.9 inches (2.3 centimeters) per year at the Pinnacles.

The San Andreas Fault as migration occurs northwestward into the Aleutian Trench is being overridden by the westward moving North American Plate. The 350-mile measurement of movement has come from the combined movements of the pre-San Andreas Faults (Elsinore, San Jacinto, San Gabriel, and Sur-Nacimiento) as well as the current trace of the San Andreas. As has occurred in the past, the future activity of the plates is expected to occur further to the east-maybe in the future at -"Landers?"-"Furnace Creek?"-"Las Vegas shear zone?".

Mining Activities

Borate

A borate prospect, called the Cuddy Canyon prospect, was located south of Frazier Park. Developed in 1917, the prospect produced colemanite borate. Because of the higher cost of production of colemanite borate, this type of borate cannot compete cost-wise with the sodium borate. The prospect is within gypsiferous-shale associated with basalt. No production records were kept.

Sand and Gravel Operations

Sand and gravel operations were developed across the road originally to supply aggregate for highway construction. The operations are in alluvial creek deposits.

Dolomite and Limestone Deposits

Limestone and dolomite deposits are located to the west. The dolomite deposit occurs in masses of brecciated, coarse-grained crystalline white dolomite interbedded with non-calcareous fine-grained metasedimentary rocks of pre-Cretaceous age. The principal mass of dolomite exposed is 200 feet long and 50 to 100 feet wide.

The limestone is pre-Cretaceous crystalline white to gray limestone deposits or outcrops occurring in roof pendants within granitic rocks. The principal mass of limestone in the pendant is 200 to 1300 feet wide and two miles long, striking northwest and dipping 40° NE.

Frazier Mountain Gold District

The Frazier Mountain District is within the vicinity of Frazier Mountain directly to the south. The region was first placer-mined in the 1840's with the lode mine Frazier Mountain opening in 1865. This and other lode-gold mines were worked fairly steadily about 1895. Minor prospecting and development work has been done in the district since, with a small production recorded in 1952.

The region is underlain by granite, granodiorite, gneiss, and schist with smaller amounts of quartzite and hornfels. The gold-quartz veins strike north, range from a few inches to five feet in thickness, and occur in shear zones that are principally in gneiss and schist. The ore is free milling and contains pyrite and small amount of other sulfides. Milling-grade ore commonly averaged ½ ounce of gold per ton. Some placer gold was recovered in the district from the streams and older terrace gravels. The mines were the Bunker Hill, Esperanza, Fairview, Frazier Mountain, Gold Dust, Harris, Hess, Maule, Sibert, and White Mule. The highest producer was the Frazier Mountain mine with $1 million production (1970 figures).

Piru Gold District

The Piru District is ten miles to the southwest of Gorman in the vicinity of Piru Creek. Placer mining was begun here in 1841 by Andrew Castillero, and gold from the district was shipped to the U. S. Mint in Philadelphia in 1842. Small scale placer mining continued intermittently through the 1890's, with more activity in the 1920's and 1930's.

The placer deposits are in and adjacent to the upper part of Piru Creek, chiefly in the vicinity of Lockwood Creek and to the east in the Gold Hill region. Gold has been recovered both from Recent stream gravels and old terrace deposits on the hills north of the Creek. The placer gold is often coarse-grained.

The lode gold is found in a number of north-striking gold-quartz veins that range from a few inches to about four feet in thickness. The veins occur in shear zones and usually in granitic gneiss or hornblende schist. The ore contains free gold and varying amounts of pyrite. Milling ore sometimes averaged ½ ounce of gold per ton. Among lode-gold mines, the principal operation was the Castaic mine, which had an estimated total output valued at about $160,000 (1970 figures).

8.7 Return to Frazier Mountain Road. Turn right, (east) towards I-5.

10.6 Turn right (south) onto Peace Valley Road, a frontage road west of I-5.
/0.0 RESET ODOMETER.

0.1 San Andreas Fault is behind low hills in foreground to the right.

0.6 The dissected alluvial fan at the base of Frazier Mountain is Pliocene Santa Margarita Formation equivalent in the upper part and Miocene marine in the lower part.

0.7 San Andreas Fault Zone.

1.3 Tejon Pass. Accelerated erosion is creating mass wasting and badlands topography in the roadcut. A few miles down the San Andreas Fault we will see examples of truncated hills which probably went through a similar landslide/erosion scenario following the large scale movement such as occurred in 1857.

Figure 2: Example of accelerated erosional processes and mass movement on a small scale due to road construction.

3.0 Turn left (east) onto Gorman School Road.

3.1 Cross under I-5.

3.2 Turn right (east) onto Gorman Post Road in downtown Gorman.

3.6 Cal-Trans gravel stockpile.

4.2 Fault crosses under the Gorman Post Road.

4.3 Bald Mountain is straight ahead.

Numerous sag ponds and straight lines of vegetation identify the fault trace.

In several places where geomorphic features such as scarps, benches, and troughs are not preserved along the main trace of the fault the location of the trace can be closely approximated because of the moist zones associated with dammed ground water. A useful guide to fault location in this case in the presence of reed-like rye grass. Since this plant only grows where near-surface water is present, the plant is rarely encountered in areas away from faults, except in a few places where springs exists in the walls of ravines or where water seeps out along the base of deeply weathered zones in the rock

units.

4.6 Power substation is within the fault zone. Built in the 1920's, the power substation is the oldest D\C current power substation on the west coast.

6.1 A sliver of the dark red (formed as miniature pinnacles) Miocene Neenach Formation has been separated from its origin located about 16 miles (25.6 kilometers) to the southeast.

7.3 California Aqueduct is straight ahead.

Turn left (east) toward Lancaster/Palmdale onto State Highway 138 (Lancaster Road).

7.7 Power substation is located within the fault zone.

8.6 Quail Lake\California Aqueduct.

Quail Lake (modified sag pond) (modified from Barrows, et al, 1985)

The main or currently active trace of the San Andreas fault dominates the structure of the Quail Lake area. Areas adjacent to the fault are characterized by a history of repeated folding and faulting, including thrust faulting, apparently associated with cumulative movement along the San Andreas fault itself. Away from the main trace, are many subsidiary or secondary faults which are not obviously active (surface features are lacking or obscure), but some faults show selected reactivation on short segments. Pleistocene and Tertiary rocks are displaced in many localities along older faults which show no evidence of Holocene activity.

This stretch of the San Andreas fault, near Tejon Pass, is very near the probable epicenter of the great Fort Tejon earthquake of 1857. Many of the features seen along the zone of recent faulting, which ranges from a single trace in places to as wide as 0.4 mile (0.25 kilometers) locally, and, rarely, 0.8 miles (0.5 kilometers), were most likely formed or freshened by the surface rupture accompanying the 1857.

9.4 Circle K Ranch.

10.3 County Road N2 (Old Ridge Route) and State Highway 138 (Lancaster Road) intersection. Continue on State Highway 138.

10.7 Old Ranch is on the right.

10.9 Turn left (south) onto the road to the National Cement Company.

11.0 Oso Canyon consist of older Quaternary alluvial deposits.

11.9 California Aqueduct.

12.4 Limestone Mine at 10:00.

14.2 Tehachapi Mountains are to the right.

15.5 STOP #3. NATIONAL CEMENT MINE AND PLANT. Pull into office building on hill to right. The National Cement Mine is located within the old Gorman or Meeke Tin District.

Meeke or Gorman Tin District

The Gorman or Meeke Tin District includes an area of about ten miles on the southeast side of the Tehachapi Mountains. Tin, zinc, and limestone have been mined from this district. Iron, scheelite (tungsten), and molybdenite are associated with the tin deposits. Minor amounts of silver and copper were prospected.

Tin

Tin was discovered in Kern County in 1940. Of the several discoveries surrounding the National Cement Mine, only one the Meeke (Hogan, Hogan-Mallery, Meek-Hogan) Mine located 2 miles (3.2 kilometers) to the east of the cement main ore body, produced ore. The mine was active from 1943 to 1945. Production was 6.7 tons averaging 39.42% tin.

The deposit consists of two cassiterite-bearing, iron-rich bodies 100 feet apart, in bleached limestone. The bodies are composed of mostly silicified hydrous iron oxide and magnetite. The mine workings consist of 14 shallow shafts and 17 trenches. Reserves were estimated to be 700 tons of 2.0% tin, 1000 tons of 1.0% tin, 1440 tons of 1.68% tin, and 20,000 tons of 0.1% tin.

Zinc

The one zinc mine within the tin district was called the Kelso (Condor, Cully Hoyes, Tejon Ranch) Mine. Located about 1.5 miles (2.4 kilometers) east of the National Cement deposit, the Kelso only operated in 1943. Production was a several tons of ore that contained 17.5% zinc, 1.97 ounces of silver, and a few pounds each of lead and copper per ton.

The deposit is a sulfide replacement of limestone near a contact with granite. Zinc mineralization, accompanied by subordinate copper, lead, silver, and iron, appears to have penetrated the limestone in veins along fractures.

National Cement Company
Limestone, Dolomite, and Cement Mining

The cement company will provide the group with a one hour tour of an active producing mine. The mine produces from a block of pre-Cretaceous (Triassic?-Paleozoic?) limestone, part of a roof pendant. The mine headquarters is just across the Kern County line from Los Angeles County. The mine is located entirely within the Meeke or Gorman Tin District.

The limestone deposits mined in this area are (Triassic?-Paleozoic?) limestone outcrops over about a seven mile area. Much of the limestone is impure and contains abundant oxides of iron, magnesium, and silicon. In many places the limestone contains layers of schist and hornfels and bodies of granite so that the limestone is present only as small bodies irregularly exposed above the less resistant rocks. Lenses of high-calcium limestone are as much as 1000 feet (305 meters) wide and 1 mile (1.6 kilometers) long.

The largest body outcrops southeast of Bear Trap Canyon. The lens is about 1¼ miles (2 kilometers) long. The width ranges from the south, 300 feet (91 meters) to 1000 feet (305 meters) to 450 feet (137 meters). Bedding is not apparent, but in plan the lens trends northwest. The deposit consists of white and gray mottled to blue-gray, fine to coarse-grained crystalline limestone. The northern part of this body is bordered on the east by a reddish-buff dolomitic limestone. Mixed limestone, granite, and schist borders on the west, south, and southeast, and to the northwest the limestone grades into dolomitic limestone occurs.

After the tour, retrace route to Highway 138.

17.1 On the left are good examples of channel dynamics of steams during flood and quiet times.

20.2 Turn right (west) onto State Highway 138 (Lancaster Road).

20.8 Turn left (south) on County Road N2 (Old Ridge Route).
/0.0 RESET ODOMETER.

The San Andreas fault is a complex network of subparallel, multiple, or left-and right-stepping traces and bands of an echelon, discontinuous, or scattered branch faults within a zone usually less than 500 feet (150 meters) wide. Some of the best exposures of the San Andreas fault are located in deep gullies north of the Old Ridge Route. In many places, however, recent alluvial deposits mask the fault and its location must be inferred from apparent offset from nearby source areas that are located across the fault.

0.2 White rocks are Quaternary Sandberg Formation.

1.3 Cretaceous Lebec Quartz Monzonite.

2.0 The thrust fault parallel to roadway lifts Pliocene Hungry Valley Formation over Cretaceous Lebec Quartz Monzonite.

2.1 Turn left (east) onto Pine Canyon Road.

2.2 On the left (north) is the Quaternary Sandberg Formation and on the right (south) is the Cretaceous Lebec Quartz Monzonite.

2.5 The break in slope and the vegetation change is the location of the fault.

3.1 Most recent break within the fault zone is at this point.

With very few exceptions, evidence of faulting between Tentrock Canyon and the hamlet of Three Points is located within 164 to 328 feet (50 to 100 meters) of the main trace of the San Andreas fault. Without actual exposures, faults north of the San Andreas fault within the Neenach Volcanic Formation (lower Miocene) and south of the fault within the crystalline basement complex are difficult to locate because of the scarcity of alluvial deposits whose displacement would preserve a record of fault movement.

3.7 Trees often appear within the San Andreas Fault Zone in arid regions due to water or spring activity. Water often uses faults as conduits in ground water circulation. Springs often surface within fault zones.

4.8 San Andreas is on the left. Red rocks to north are Oligocene volcanic rocks and are dated as older than the Miocene Neenach Formation at Three Points.

5.7 Linear sag pond.

6.3 Cretaceous Lebec Quartz Monzonite to right (south) and Tertiary sediments on left (north).

6.9 Pliocene Hungry Valley Formation is in the roadcut.

7.0 Sag pond.

7.7 The house is built within the San Andreas Fault.

7.9 Limestone roof pendant.

8.7 Running Well Ranch.

9.0 Miocene Neenach Volcanics Formation is on the left.

Rocks in this area belong to the lower Miocene Neenach Volcanic Formation first described by Matthews (1976), and renamed the Neenach Volcanics by Sims (in press). The Neenach Volcanics were named after Neenach School. The outcrops in the hills surrounding are white to pale purple red, aphanitic, flow-banded rhyolite. The volcanic rocks extend about 5 miles (8 kilometers) to the west, where andesite and dacite flows and perlite predominate.

The volcanic eruptions of the formation begin about 24 million years ago. The magmas were generated as the Mendecino triple junction migrated northward, and left behind a no-slab region that was filled by subcontinental mantle. The volcanic sequence started with masses of rhyolitic lava erupting from at least five vents as flows from an older quartz diorite. During the eruptions, the magma varied form andesitic and basaltic to mainly rhyolitic. Towards the end of the eruptive cycle, some of the vents became plugged, and periodic steam eruptions blasted out of the plugs. The estimated total volume of the volcanic material originally erupted is 6 to 10 cubic miles (25 to 40 cubic kilometers). Most of the material has been eroded. The original height of the tallest volcano is estimated to have been about 8500 feet (2580 meters).

The Neenach Formation is a thick sequence of coarsely stratified rhyolitic pyroclastic deposits, chiefly volcanic breccia, with some tuff and agglomerate. The formation has seven recognized members. In ascending order, the member units are the rhyolite member, the pumice lapilli-tuff member, the andesite member, the agglomerate member, the dacite member, the porphyritic rhyolite member, and the rhyolitic breccia member. The final color of the formation was dependent on the amount and chemical content of the steam (water) present at the time of the eruption.

The Neenach Formation is an excellent example of the measurement of horizontal displacement of the San Andreas Fault. Similar geochemical and age characteristics have confirmed the correlation of three areas along the San Andreas at the Pinnacle Volcanics, the volcanic rocks of Lang Canyon near Parkfield, and the Neenach Volcanics between Gorman and Palmdale. Since the initial eruption of the once common Neenach-Pinnacles Volcanics, the formations have been offset about 197 miles (315 kilometers) by the San Andreas Fault. At Lang Canyon, west of Parkfield, is a sliver of the Neenach-Pinnacles Volcanic Formation that was separated from the Pinnacles Formation as the fault migrated northwesterly. Displacement of the Lang Canyon segment is about 59.5 miles (95 kilometers) from the Pinnacles Formation and 137.5 miles (220 kilometers) from the Neenach Formation.

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Blockfaulting preserved the Pinnacles Volcanic Formation within the older Santa Lucia Quartz Diorite of the Gabilan Range. The Neenach Formation was not subject to downfaulting and has been very heavily eroded.

9.1 At the mouth of Garden Gulch, a backhoe trench 262 feet (80 meters) long was dug across the main trace of the San Andreas fault in ponded alluvial deposits. Samples of charcoal taken form debris filling a large fissure (inferred to be related to a surface-faulting event prior to the 1857 earthquake) yielded an average date of origin of 1641 +/- 41 AD (Rust, 1982a). From this evidence, Rust (1982a) concluded that recurrence interval is apparent of about 160 years for major earthquakes along this stretch of the San Andreas fault.

9.8 Kimbrough Canyon to the right.

9.9 Soil formation is occurring on two distinct formations. The Neenach volcanics form a steep slope against more-erodible quartz monzonite (See Figure #3).

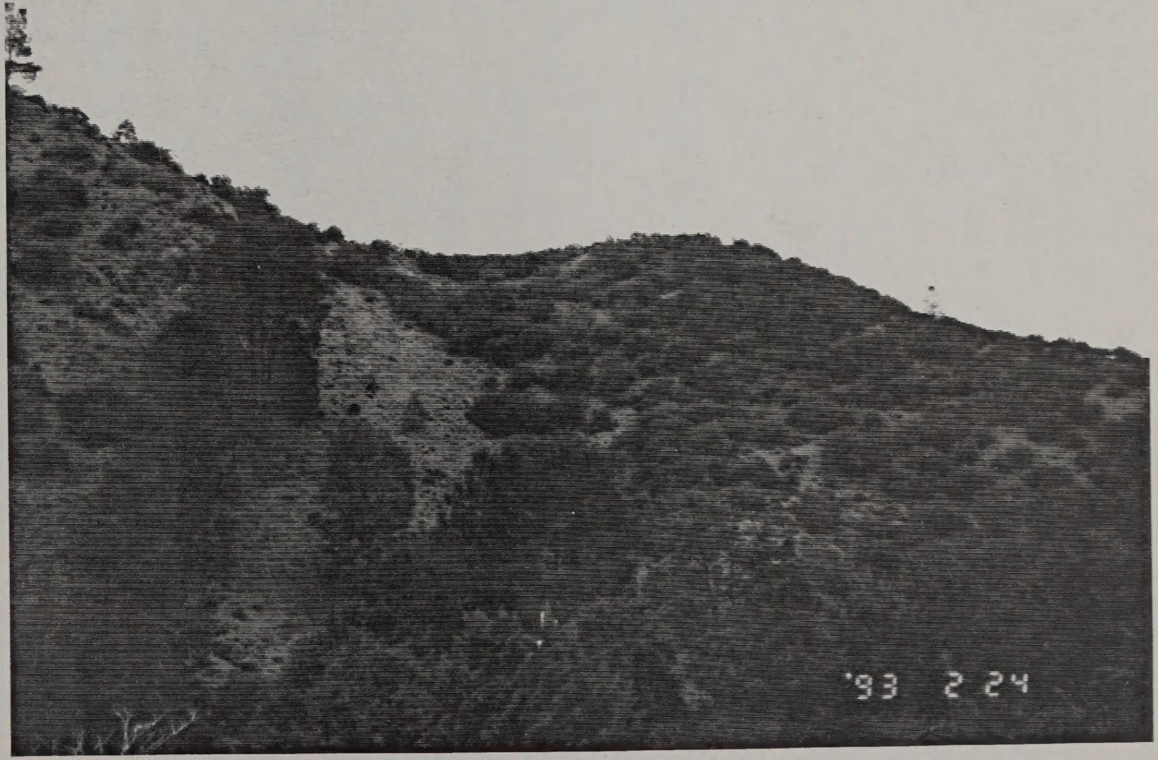


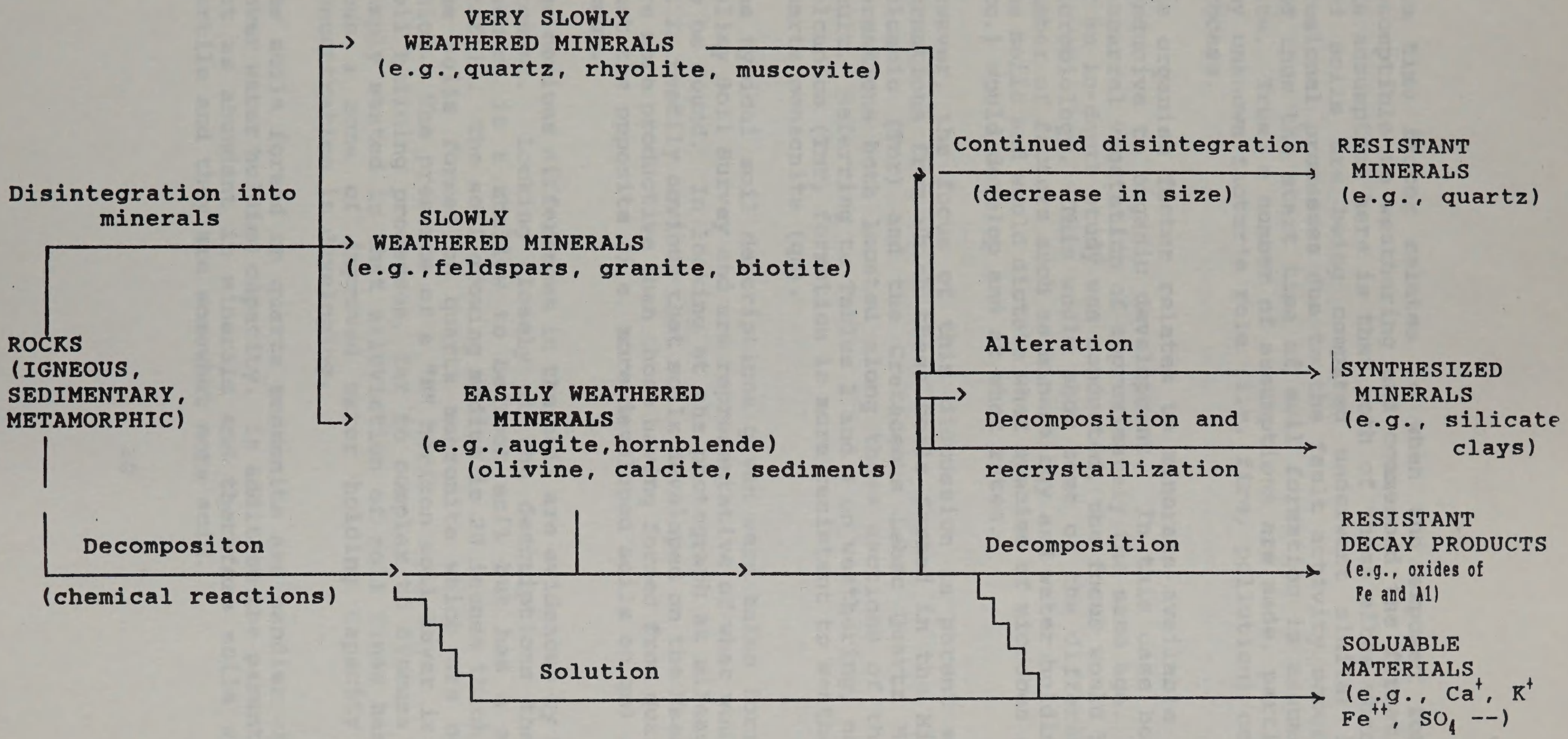
Figure 3. Soil and vegetation contrasts along the San Andreas Fault. To the left is Neenach volcanics. To the right is quartz monzonite. View is toward the southwest.

MINERAL WEATHERING & SOIL FORMATION

Early Soil Scientists regarded five factors as important in soil formation - climate, organisms, parent material, relief, and time. More recently, further observations have realized that hydrological and anthropogenic (human) factors (previously included with relief and organisms, respectively) are at least as important as the other five. However, all seven factors are interdependent to some extent, and most are multiple variables (i.e. organisms include the separate effects of fauna and flora). Quantification of the individual or combined effects is often difficult to differentiate.

Along this section of the San Andreas Fault, an opportunity is occurring to compare soil formation on two distinct formations, focusing on one of the soil formation factors, parent materials. The climate factor is none arguable, mediterranean, with the same elevation and aspect. Relief would be a consideration, however, as the soil type comparison is on sites with the same aspects, with approximately the same type of topography, truncated hillsides, and is presumed to have been disturbed during the last major fault activity.

TABLE #2


VERY SLOWLY WEATHERED MINERALS (e.g.,quartz, rhyolite, muscovite)
Disintegration into minerals
SLOWLY WEATHERED MINERALS (e.g.,feldspars, granite, biotite)
ROCKS (IGNEOUS, SEDIMENTARY, METAMORPHIC)
EASILY WEATHERED MINERALS (e.g.,augite,hornblende) (olivine, calcite, sediments)
Decompositon (chemical reactions)
Solution
Continued disintegration (decrease in size)
RESISTANT MINERALS (e.g., quartz)
Alteration
Decomposition and recrystallization
SYNTHESIZED MINERALS (e.g., silicate clays)
Decomposition
RESISTANT DECAY PRODUCTS (e.g., oxides of Fe and Al)
SOLUABLE MATERIALS (e.g., Ca$^+$, K$^+$ Fe^{++}, SO$_4$ --)

The time factor relates to when the exposed formations were susceptible to weathering and commenced the formation of soils. The assumption here is that both of these sites where the geology and soils are being compared underwent similar landslide and erosional processes due to the fault activity occurring in 1857. And thus the start time of soil formation is assumed to be that date. True, a number of assumptions are made, particularly since any unknown factor's role (i.e. fire, pollution) could alter the process.

The organism factor relates to minerals available and processes conducive to organic development. In this case both sites have chaparral vegetation of approximately the same age. As for fauna, if an in-depth study was conducted, the focus would be on the soil microbiology. This would show some of the differences due to a number of factors such as mineralogy and water holding capacity of the soils and would dictate what species of microbes (fungi, lichen etc.) would develop and at what rates.

However, the focus of this discussion is parent materials, the formations from which these soils formed in the Miocene Neenach Volcanic (Tnr) and the Cretaceous Lebec Quartz Monzonite (qm) formations both located along these sections of the San Andreas Fault. Referring to Tables 2 and 3 on weathering, notice that the volcanics (Tnr) formation is more resistant to weathering than the quartz monzonite (qm).

The typical soil descriptions given were taken form the Antelope Valley Soil Survey and are representative of what would be expected to be found. In looking at the photograph at mileage marker 9.9, it is readily obvious that soils developed on the Neenach Volcanics are more productive than those having formed from quartz monzonite. Just the opposite (i.e. more developed soils on qm) is expected to occur.

The obvious differences in the soil are evidenced by the vegetation present. Looking closely at the descriptions the soil on the Neenach is a shallow to bedrock soil but has a more developed profile. The soil growing medium is 20 inches thick as opposed to the soils formed on quartz monzonite which are only 12 inches thick. The presence of a "B" horizon soil layer is indicative of soil building processes, far to complex to discuss at length but simply stated is that alluviation of soil fines has occurred and thus a zone of improved water holding capacity and nutrient concentration is developing.

The soils formed on quartz monzonite are sandier and thus have a lower water holding capacity. In addition the parent materials are not as abundant in minerals and therefore soils will not be as fertile and they are somewhat more acid.

Table 3. Soil Descriptions

Soils on Quartz Monzonite (qm)

Amargosa rocky coarse sandy loam, 9 to 55 per-cent slopes, eroded (AmF2).--This is the only Amargosa soil mapped in the Area. It is on hilly uplands in the central part of the survey area. In most places from about 25 to 40 percent of the original surface soil has been removed through moderate sheet and rill erosion. Rock outcrops cover 2 to 10 percent of the surface, and many areas are cut by shallow gullies.

A11--0 to 2 inches, brown (10Y 5/3) coarse sandy loam, dark brown (k10YR 4/3) moist; weak, fine and medium, subangular blocky structure; soft when dry, very friable when moist, non-sticky and non-plastic when wet; common micro and very fine roots; common micro irregular pores; slightly acid (ph 6.2); abrupt, smooth boundary; horizon 2 to 3 inches thick.

A12--2 to 13 inches, yellowish-brown (10YR 5/4) coarse sandy loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; common micro roots and a few very fine roots; common micro irregular pores and a few very fine tubular pores; about 3 to 5 percent, by volume, is gravel; slightly acid (ph 6.5); gradual, wavy boundary; horizon 8 to 11 inches thick.

C--13 to 18 inches, yellowish-brown (10YR 5/4) gravelly sandy loam, dark yellowish brown (10YR 4/4) moist; massive; slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; common micro roots; common micro irregular pores; about 20 percent, by volume, is fine gravel; slightly acid (ph 6.5); gradual, wavy boundary; horizon 4 to 6 inches thick.

Soils on the Neenach Volcanic Formation (Tnr)

Temescal-Rock land complex, 30 to 50 percent slopes (TrF).--This is the only unit mapped in the Temescal series in this Area. It is in the north-western part of the survey area. About 50 percent is Temescal sandy loam, 30 to 50 percent slopes, and 45 percent is Rock land. Rock land is described in this survey in alphabetical order.

A1--0 to 5 inches, light brownish-gray (10YR 6/2) sand loam, dark grayish brown (10YR 4/2) moist; moderate, fine, subangular blocky structure; slightly hard when dry, friable when wet; many micro roots and a few very fine roots; common micro irregular pores and a few very fine tubular pores; about 5 percent, by volume, is andesite gravel; slightly acid (pH 6.5); clear, wavy boundary; horizon 4 to 5 inches thick.

B2--5 to 20 inches, light brownish-gray (10YR 6/2) heavy sandy loam near loam, dark grayish brown (10YR 4/2) moist; massive; slightly hard and hard when dry, firm when moist, non- sticky and slightly plastic when wet; common micro roots and a few very fine roots; common micro irregular pores and a few very fine tubular pores; slightly acid (pH 6.5); gradual, wavy boundary; horizon 10 to 15 inches thick.

R1--20 to 26 inches, slightly weathered light--gray andesite. R2--26 to 30 inches, slightly weathered, light-gray andesite that includes a few lenses of interbedded soft tuff.

In conclusion, on the basis of the weathering table, the formation of the soils would seem to be most conducive on the quartz monzonite (qm) materials. However, one overriding factor may have to do with grain size of raw minerals, the rhyolite (Neenach Volcanics) having a finer grain size than the quartz monzonite. Even in an original state, water holding capacity would be better in the rhyolite. And thus, this may have resulted in a more developed soil in the Neenach Volcanics. Or, this may not be representative of soil descriptions (i.e. the Neenach Volcanics may be much older than the soil formed on quartz monzonite (Actually, the Neenach Volcanics are younger than the quartz monzonite).

10.1 At Three Points, turn right (south) onto Pine Canyon/Elizabeth Lake Road.

Three Points (modified form Barrows, et al, 1985)

South of Three Points, in the vicinity of Oak Flat, south of the fault zone, is an area of anomalous topography, was thought to be a possible ancient landslide. Although topographic evidence, in the form of arcuate margins and the closed depressions at Oak Flat, strongly implies that the anomalous topography is a landslide, quartz monzonite and rocks of the diorite gneiss complex appear to be undisturbed within the outlined area and in the adjacent terrain. A contact between the rocks, that traverses the "slide" area, does not appear to be offset.

In addition, an area of older alluvium consisting of coarse, stream-deposited debris, partly derived from the slopes south of the San Andreas fault, lies just north of the fault in this area and appears to have been off-set form the source area south of the fault area movement along the fault. Rust (1980) refers to this older alluvium as "a large landslide which has been bisected and offset some 131 feet (40 meters) by displacement on the main trace of the fault". Several lines of evidence suggest that this may not be so. What appears, from shape and dimensions on air photos, to be the offset landslide mass including rocks of the Hungry Valley Formation overlain by stream-deposited debris from south of the fault. The debris contains additional rock types, such as hornblende diorite, quartz and gneiss, which have not been recognized within the area south of the fault outlined as a possible ancient landslide. The ambiguous nature of the geological relations within units north of the fault reduces the significance of inferences about fault displacement in the vicinity of the possible ancient landslide. This unit cannot be used to correlate the motion of the San Andreas Fault.

Mining Activities

Silver

Located 4 miles (6.4 kilometers) south of Three Points within the Los Padres National Forest is the Gillette (Las Padres) mine. Reportedly the mine yielded an undetermined large amount of silver and minor amounts of gold when in operation in the 1880's. Possibly part of the Mount Gleason Mining District, the mine has been long abandoned.

Neenach Gold Mining District

The Neenach District in northern Los Angeles County is located about two miles northeast of Three Points. Gold was discovered in 1899, but the bulk of the production of about $200,000 was obtained in 1935-38. Intermittent mining and development has occurred since the 1930's. Most of the production has been from the Rivera or Rogers-Gentry group of mines.

The ore deposits occur in a contact zone between metasediments and quartz monzonite. The ore bodies consist of zones or narrow quartz veins and stringers containing fee gold and varying amounts of pyrite. The oxidized zone yielded material valued as high as $60 of gold per ton (1970 figures).

10.4 Cretaceous Lebec Quartz Monzonite Formation is on both sides of the roadway. San Andreas Fault Zone is 1 mile (1.6 kilometers) to the right (south).

<u>San Andreas fault.</u> Through the Three Points segment the San Andreas fault consists in places of a simple, single trace, while in other segments, the fault is a complex network of subparallel, multiple, or left- and right-stepping traces of an echelon, discontinuous, or scattered branch faults within a zone commonly less than 500 feet (150 meters) wide. As elsewhere, recent alluvial deposits or artificial fill mask the fault in places. The location of the fault must be inferred from displaced surfaces or from the composition of younger alluvial deposits apparently offset from nearby source areas that are located across the fault.

The Three Points area is within 12 to 19 miles (20 to 30 kilometers) of the most likely epicenter of the great earthquake of January 9, 1857. Many of the well-preserved and fresh-appearing features, such as the abundant benches and troughs in the alluvial deposits of the Sandberg Formation or other gravels, were probably formed or renewed by surface rupture accompanying the 1857 earthquake.

11.7 En Echelon faulting parallels the fault zone.

12.8 Sag pond.

13.0 Los Angeles Prayer Mountain Ranch formerly the Sawmill Mountain Ranch. The road rejoins the fault zone.

12.1 North facing fault scarp is to the right (south).

Pine Canyon (modified from Barrows et al, 1985)

Along much of the length of the fault within the Pine Canyon segment the San Andreas fault occurs as a simple, narrow, single fault trace along which the granitic rocks of Portal Ridge are juxtaposed against the gneissic rocks of Sawmill Mountain.

Except for a few, possibly early Tertiary or older faults that lie entirely within basement rocks, all faults in this area are probably related to movement along the San Andreas fault and, as such, are considered to be within the San Andreas Fault zone. This includes not only the San Andreas Fault, (also referred to as the main trace or most recently active trace, along which surface disruption occurred during the 1857 Fort Tejon earthquake,) but also includes subparallel faults on Sawmill Mountain as well as in Pine Canyon.

14.1 King's Canyon is to the right.

14.8 The road to the right goes to the Sawmill Campground.

One other notable exposure of the San Andreas fault was formed very recently of deep gullying of ponded alluvium at the mouth of Heryford Canyon just west of Hidden Lake. Here, the San Andreas fault is vertical and separate sandy arkosic alluvium on the north formed from contorted, clayey, organic, ponded alluvium on the south.

15.0 Hideaway Canyon is to the right.

At several places, exposures of the San Andreas fault can be examined. A typical example is the streamcut exposure 3700 feet (0.7 kilometers) east of Lower Shaker Campground. Here medium-to coarse-grained, equigranular, "salt and pepper" granodiorite on the north is in fault contact ranges from 0 to 1.6 inches (0 to 4 centimeters). Within a distance of less than a meter from the fault the primary igneous and/or metamorphic textures in the rocks, although crushed, are not greatly disturbed by shearing. Near this locality the deeply gullied roadcut with badland-like erosional features in granodiorite, along the north side of Pine Canyon Road, exposes granodiorite that is crushed (grain boundary separation) but evidently only weakly sheared because primary textures are not obliterated.

Another fault-bound deposit of older alluvium, on the north side of the main trace, lies along Pine Canyon Road near the roadside rest. This deposit contains abundant, blocky, marble debris probably derived from landslides that originated across the San Andreas fault to the south. Erosion along the northern branch fault by Pine Canyon Creek has exposed brecciated greenish basement rock in the creek bed west of the roadside rest. Downcutting has isolated the older alluvium-capped block between Pine Canyon Road and the San Andreas fault.

Geomorphic features such as small closed depressions and shallow troughs are easily obliterated by alluvial fill and are not likely to persist. Those that do exist can be inferred to have formed or been renewed during the faulting which accompanied of a the Fort Tejon earthquake of 1857. Features that might provide evidence of a lateral component of faulting in the Pine Canyon segment are much less common than those featured that commonly imply a vertical component of fault movement such as scarps, benches, and depressions.

Offset stream channels between Hideaway Canyon and Bushnell Summit are probably the best evidence of right-lateral faulting along this segment. At no place, however, can a simple, single offset likely to have resulted from the 1857 fault movement be measured. Through measured offsets along the San Andreas fault between Corona Del Valle, west of Three Points, and Leona Valley, Sieh (1978) implies that right-lateral offset ranging from 11 to 20 feet (3.5 to 6 meters) is likely to have occurred in the Pine Canyon segment at the time of the 1857 Fort Tejon earthquake.

15.5 Granodiorite on left of San Andreas Fault, Cretaceous Lebec Quartz Monzonite to the right.

15.6 Sawmill Mountains are on the right. The mountains are Mesozoic granites and Pre-Cambrian gneiss.

The basement rock relations in the roadcut exposure suggest a simple fault history. This inference is contradicted in areas where deformed older alluvial deposits along the fault have not yet been removed by erosion. At Bushnell Summit and along the Sawmill Mountain Truck trail, near the junction with the Pine Canyon Road, a weakly stratified, well-consolidated deposit of poorly sorted older alluvium has been folded into a syncline whose axis parallels the San Andreas fault.

16.5 Blaisdell Road.

16.8 Dimension stone company.

17.4 Truncated Hillside. Compare to "Badlands" roadcut at Tejon Pass. (See Figure #2 and #4).

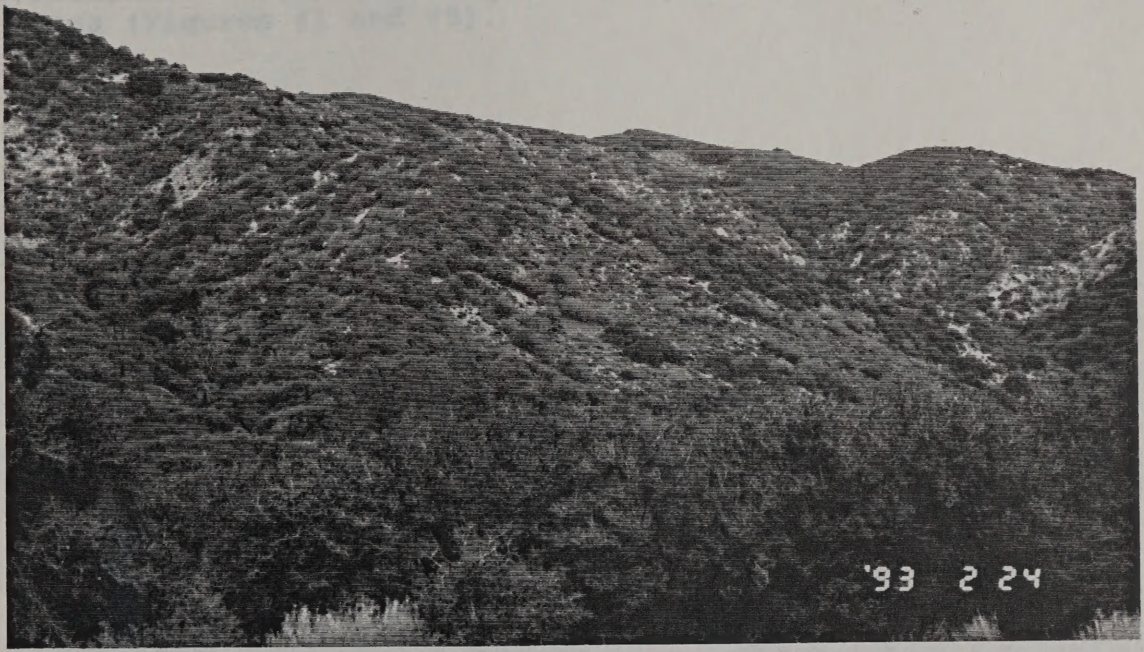


Figure 4. Truncated hillside on left (north) side of roadway near Hughe's Lake.

Accelerated erosional processes and landslide activity resulting in dynamic and rapid alluviation are associated with post fault movement activity. Truncated hills left exposed after slides and devoid of stabilizing vegetation eroded away, filling and masking over fresh fault lines, and obliterating other features due to faulting. The small scale example of this activity adjacent I-5 (Tejon Pass) near Frazier Park gives us some idea of the magnitude of post fault erosional and mass movement activity that probably occurs following major fault activity.

17.8 Spanish style two story home is built directly on the fault.

Between Pine Canyon and Elizabeth Lake the main trace of the San Andreas fault is more obscure than to the east. This results largely from the location of the fault in a narrower, more confined Valley where cultivation and other activities have disturbed the natural ground surface and destroyed any subtle fault features that may have been present. In addition, dynamic and rapid alluviation west of Hughees Lake has also helped to obliterate fault features. Although only

poorly and intermittently exposed west of Elizabeth Lake, the faults presence in the valley bottom is readily deduced from nearby exposures of sheared basement rock and granitic basement rocks of contrasting composition found on opposite sides of the valley.

18.5 Truncated Hillside. Compare to "Badlands" roadcut at Tejon Pass (Figures #1 and #5).


'93 2 24

Figure 5. Truncated hillside on right (south) side of roadway near Hughe's Lake.

18.8 The Oaks sign is in weathering granodiorite.

19.6 Lake Hughees (modified sag pond). Pine Canyon Road becomes Elizabeth Lake Road.

Lake Hughees (modified from Barrows et al, 1985)

The Lake Hughees segment is dominated by a long narrow valley bounded by Portal Ridge on the north and the Sawmill Mountain-Grass Mountain ridge on the south. All faults within this segment are considered to be within the San Andreas fault zone, which includes the modern, main trace of the San Andreas fault, where rupture occurred in 1857, and subparallel faults, spatially and tectonically associated with the main trace. The sub-parallel faults form a broad band up to 1.8 miles (3

kilometers) wide centered about the main trace of the San Andreas fault and include both older, abandoned traces of that fault and its secondary branch faults that appear to have been selectively reactivated during large earthquakes.

To the right (south) is decomposed granite and to the left (north) is granodiorite.

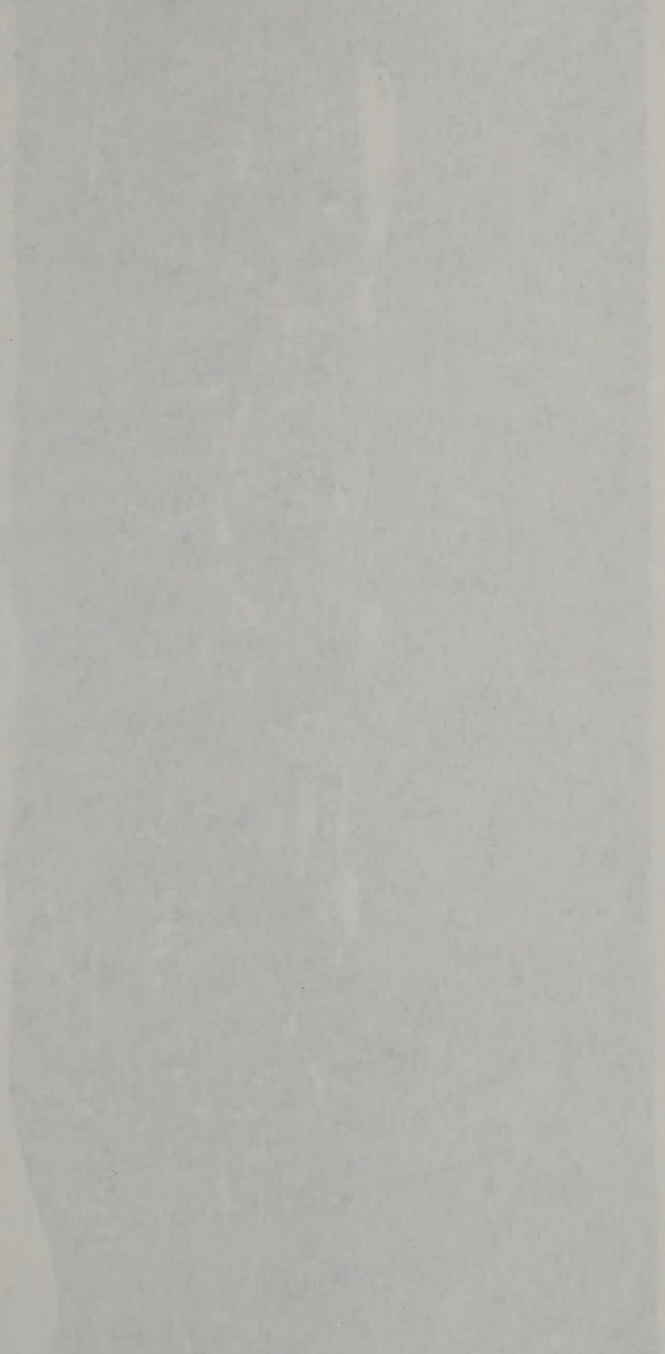
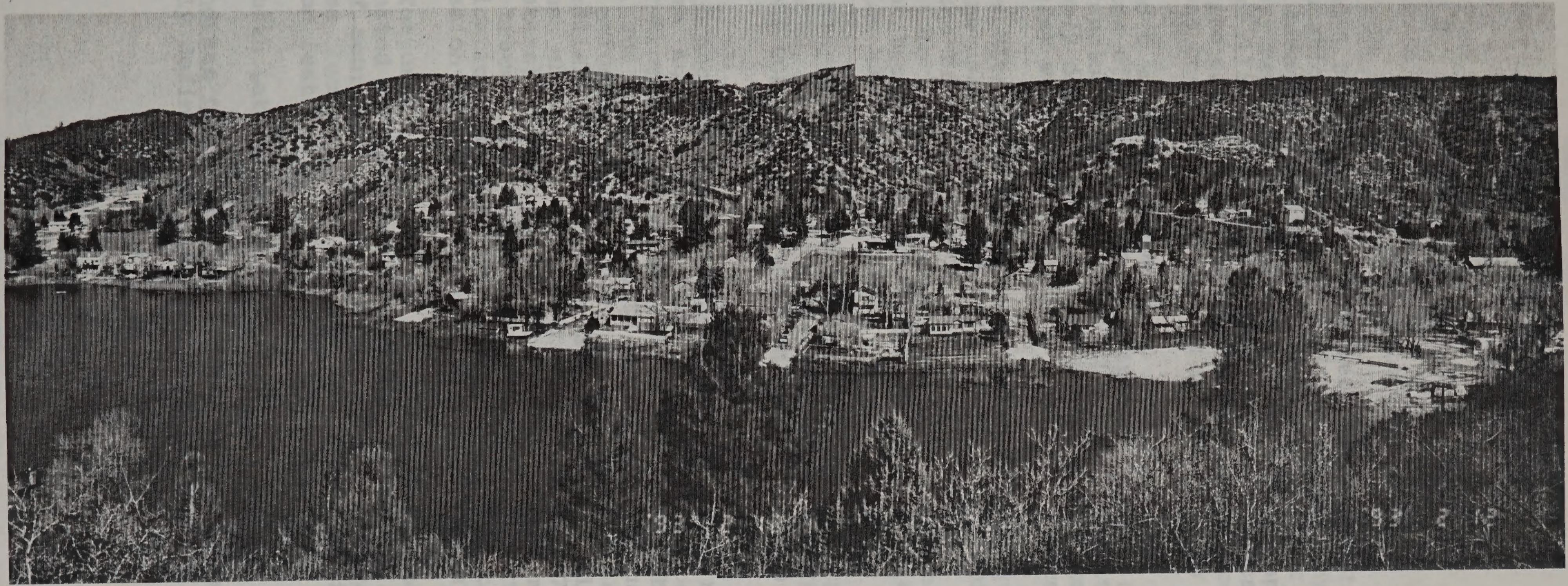


Figure 6. Lake Hughes, a sag pond along the San Andreas Fault Zone.


'93 2 12

Mining Activities

Graphite

Located 1.5 miles (2.4 kilometers) south of Lake Hughes was the location of the Western Graphite Company. Called the Black Diamond deposit, the operations took place in the 1930's. Production is undetermined. The graphite was found in crystalline limestone, quartzite, and feldspar-sillimanite-tremolite schists. The 50-ton flotation mill connected to the mine was converted in 1935 for custom milling of gold ore.

Located 5 miles (8 kilometers) south of Lake Hughes was the location of the California Graphite Company (Flake, Prince, San Francisquito Canyon deposit). The graphite was found in a steeply dipping graphite schist deposit 8 to 25 feet (2 to 8 meters) wide and over 1 mile (1.6 kilometers) in length.

The graphite was mined by open cuts and underground workings. The mine used a 1500 foot (457 meters) long aerial tramway to haul the ore to a 50-ton dry process mill. Concentrations from 7% to 17% graphite were mined at the rate of 10 tons per day for local use in foundry facings, paint, and lubricants. The mine has been idle since 1923.

19.8 LUNCH STOP AT LAKE HUGHES COMMUNITY CLUB. DUE TO AREA WATER SHORTAGES, ANOTHER STOP FOR RESTROOM FACILITIES WILL BE MADE FOR YOUR CONVENIENCE AT LAKE ELIZABETH TWO (2) MILES FROM THE CLUB.

<u>North branch of the San Andreas fault.</u> The north branch of the San Andreas fault forms the northern boundary of the center-trough ridge north of Lake Hughes-Lake Elizabeth. This fault, and equivalent faults in the east Leona Valley in the same structural position, form the longest continuous subparallel member of the San Andreas fault zone in Los Angeles County, stretching more than 37.5 miles (60 kilometers) to the east. The north branch merges from the main trace near the Munz Canyon. Extensive recent modification by man has destroyed most of the surface expression of the fault in this critical area.

The features visible on 1928 aerial photos have been eliminated by construction of dams enlarging Elizabeth Lake, a golf course, a housing development, and by farming. The precise location of the trace cannot be determined from surface features.

21.8 Elizabeth Lake (modified sag pond).

<u>San Andreas fault.</u> The main trace of the San Andreas fault is clearly defined and fresh appearing south of Elizabeth Lake

and east of the old Munz Ranch, where the fault forms the southern structural boundary of the sandstone of the Anaverde formation. The relatively resistant nature of the arkosic rocks to erosion has provided enough local relief for the formation and preservation of many geomorphic fault features along this stretch of the San Andreas fault.

Linear gullies, trough, ridges, and swales are common along this part of the fault, as are the more ephemeral fault features such as closed depressions, ponded alluvium, and offset channels. The youthfulness of the features supports the interpretation of surface faulting along the San Andreas fault through the entire Lake Hughes segment as a result of the 1857 Fort Tejon earthquake. With the exception of minor left and right steps of up to 6.5 feet (2 meters), this part of the fault forms a continuous, straight trace more than 2.5 miles (4 kilometers) striking N 65 degrees W that nowhere varies in dip more than 5 degrees. Small, subparallel branch faults in this area lie both north and south of the main trace, typically in a zone less than 650 feet (200 meters) wide.

South of Elizabeth Lake deflected drainages imply that at least 8 feet (2.5 meters) of right-lateral offset resulting from the 1857 earthquake. Sieh (1978b) reports similar offsets averaging 11.5 feet (3.5 meters) for the Lake Hughes-Leona Valley areas, but his curve of the smallest offsets (Sieh, 1978b) shows a gradual increase in the offsets to an average of 20 feet (6 meters) beginning just west of the Lake Hughes segment. This change in 1857 offsets suggest that fault displacement east of Lake Hughes may have occurred among several active subparallel faults and was not confined to a single, main San Andreas fault strand. Geologically, this inference is supported by the fact that the north branch of the San Andreas fault, which has evidence of recent activity, probably including the 1857 event, diverges from the main trace of the San Andreas fault just west of Elizabeth Lake near the mouth of Munz Canyon. If subparallel faults have accommodated a portion of the total slip east of the Lake Hughes area, offset alluvial units would confirm this. The lack of displaced older units in this segment makes it impossible to quantify the components of slip taken up by the various subparallel faults.

A long south facing scarp extends for over 2 miles east of Lake Elizabeth on the south side of the lake.

22.8 Turn right into the Angeles National Forrest Day Use Area for a rest stop.

24.1 Turn right (westerly), staying on Elizabeth Lake Road not Johnson Road.

\0.0 RESET ODOMETER.

0.5 Cross the fault.

0.8 San Francisquito Canyon Road. Veer to the left and continue southeast on Elizabeth Lake Road toward Palmdale.

1.0 Decomposed granite is to the south and Pliocene Anaverde Formation is to the north. An old windmill is on the left side of the road.

1.7 Pitchfork Ranch. Amagosa Creek is to the right (south) of the road.

2.6 West half Leona Valley (modified from Barrows, et al, 1985)

<u>General</u> A dramatic contrast in the style of faulting along the San Andreas fault zone between the western and eastern halves of the area characterizes this segment. A chaotic-appearing jumble of short fault segments is replaced abruptly by the nearly perfect parallelism between the main trace and the north branch starting to the west 1150 feet (350 meters) of the Leona Valley Ranch (Wallace, 1949).

As is typical of the San Andreas fault elsewhere, its dominance as a factor affecting the development of the terrain is reflected in the topography. The center-trough ridge lies between Portal Ridge on the north and Leona Valley, which, in this segment, is essentially a narrow trough south (left) of Elizabeth Lake Road through which the Amargosa Creek flows. South of Leona valley is a massive ridge separating the San Andreas fault zone from the Sierra Pelona area.

<u>San Andreas fault.</u> An exceptional aspect about the eastern stretch of the main trace is the abundance of features that imply recent of faulting as opposed to the presence of faulting. The youthful-appearing features include offset channels, gullies, and ridges, and deflected drainage and beheaded channels. The freshness of the features is very likely due to formation or renewal during the 1857 Fort Tejon earthquake. Since the entire area of the fault covered in this field trip is inferred to have been the site of surface rupture during the 1857 event, the excellent preservation of so many small features along this particular stretch needs to be explained. The preservation is probably due, in large part, to the presence of the center-trough ridge which prevents drainage from Portal Ridge from crossing the fault.

Among the fresh features referred to above are offset gullies. In a 3300 feet (1 kilometer) stretch of the fault, just north of Elizabeth Lake Road, the measured amount of right-lateral offset of a dozen of the gullies ranges from 8 to 20 feet (2.4 to 6 meters) with the average being 15 feet (4.5 meters). Larger offsets, for example, a channel offset of 85 feet (26

meters), also occur along this stretch.

Some of the offset gullies with apparent displacement of 10 to 16.4 feet (3 to 5 meters), have a different shape where the channel is coincident with the fault trace. Some channels have not been reestablished by erosion subsequent to the fault displacement. Other offset gullies of the same size have a through-going channel on the fault trace, reestablished by erosion. Therefore, gullies with ponded alluvium or a disturbed surface at the point of offset may be younger than those where drainage has been re-established. If the small gullies are unique, as appeared to be, then gullies should hold some similar-appearing features to suggest a progressive topographic cycle. Unfortunately, the measurement of the time frame of the cycle is impossible to calculate. The time frame for the alternative interpretations is critical in estimating how often the fault moves. If gullying is a cyclic sequence, such as smoothing of the slope or scarp, gullying, faulting, and smoothing again, then thousands of years may be involved. If gullying is less frequent than faulting, the gullies are simply a unique index to the amount of most recent displacement.

The vastly different character of the main trace in the western half of the segment is almost certainly related to chaotic structure in the readily deformed Pliocene Anaverde clay shale. Landsliding is common in this area which has the greatest relief of any area along the center-trough ridge. Many of the landslides are active and mobility of the ground surface has probably contributed to the obliteration of features due to faulting. According to local residents, very fresh-appearing cracks were observed during field work on landslides which may have been reactivated at the time of the 1971 San Fernando earthquake.

Significantly, the kinds of features in the western part of the main trace are those indicative of the presence of faults. The most common features are benches, notches, and troughs. A lack of features resulting from lateral movement implies a dispersal of displacement over a broad area.

<u>North Branch of the San Andreas fault.</u> The north branch of the San Andreas becomes ill-defined, obscure, and even invisible in western Leona Valley. As the center-trough ridge appears, the northern segment of the fault is defined by precisely bound traces of the features of faulting such as scarps, benches, and troughs abundant along the north branch. Some of the features, in particular where troughs are spatially associated along the fault with a linear ridge, maybe the result of a lateral component of displacement.

The most prominent features are closed depressions, some of

which become sag ponds during wet years. A core hole was drilled in the largest sag pond along the north branch about 33 feet (10 meters) north of the fault scarp (Kahle, Smith, and Beeby, 1975, hole no. 24R). The drill penetrated about 94 feet (28.5 meters) of alluvial materials before bottoming in Pliocene Anaverde Formation, the breccia member. Successive layers of silt, sand, and gravel from local source rock encountered in the core may be mixed alluvial and lacustrine deposits related to periodic renewal of the depression by fault activity.

The freshness of features along the north branch suggest renewed movement in 1857. Accordingly, this stretch of the north branch should be considered as likely to be the site of surface rupture as is the main trace in future earthquakes.

4.3 Pre-Cretaceous Portal Schist Formation is to the left (north).

6.2 Quaternary alluvial deposits on flanks of valley lie upon Pre-Cretaceous Portal Schist Formation to the north and decomposed granite to the south.

6.3 Stop sign. Town is called Leona Valley.

East half Leona Valley (modified from Barrows et al)

General. Leona Valley is both an expression and a consequence of the long history of movement along the faults of the San Andreas fault zone. The main trace, labelled San Andreas fault on the map and the nearby, parallel north branch are well expressed in the "rift zone" that lies between Portal and Ritter Ridge on the north and Sierra Pelona-Leona Divide on the south. The fault strands also define the boundaries of the slightly uplifted center-trough ridge. Numerous faults of various kinds are scattered across the alluviated terrain of Leona Valley, as well as along the slopes of the bordering mountains. In contrast to the narrow, trough-like nature in the western Leona Valley, the broadening of the eastern section of the Leona Valley, near the mouth of Bouquet Canyon is related to the presence of the San Francisquito fault, along which dissimilar rocks are juxtaposed.

San Andreas fault. Across most of this segment the San Andreas fault follows a fairly straight and simple course. At the eastern end, however, faulting is much more complicated where the Powerline thrust fault impinges upon the main trace. In this area, within 164 feet (50 meters) of the main trace, subtle fault features such as small closed depressions and scarplets, are well preserved. The area is an exceptionally good place to view the "micro features" because erosion has been minimal along the crest of a linear ridge due to low local relief. The small branch faults are represented by chains of miniature closed depressions (less than 11.8 inches (30 centimeters) relief) or lines of pebbles and cobbles which mark an abrupt change is slope angle. The branch faults diverge from the trend of the main trace by 10-20 degrees, oriented as radial shears on a right-lateral system (Tchalenko, 1970). Some can be followed for 790 feet (240 meters), but most are shorter than 328 feet (100 meters) and commonly separate different rock types. These form a zone of faulting 49 to 164 feet (15 to 50 meters) wide centered on the main trace. The possibility exists that some of the very small closed depressions maybe nearly filled remnants of collapse fissures.

Fault features scattered along the main trace are sparse or non-existent across much of the segment due, in part, to disturbance of the ground surface by human activities, including roadbuilding along Elizabeth Lake road. West of the intersection of 90th Street West and Elizabeth Lake Road the density and clarity of features is unusually good. This clustering includes small shutter ridges, troughs, benches, and offset ridges, channels, and/or gullies that are well

preserved probably because formation or renewal occurred during the 1857 earthquake. Another reason for the abundance along this stretch of the fault may be due to the presence at and/or near the surface of Anaverde clay shale which is readily deformed due to its plastic nature.

The amount of shearing in rocks adjacent to the San Andreas, particularly basement rocks or rocks of Tertiary age, is commonly developed to the point where the rock is incoherent. This is observable in stream cuts exposing the fault. Another common feature is very thin slices of the same rock types, usually too small to map occurring on both sides of the main trace. Some authors have characterized the fault as separating diverse rock types but in many places, this is not the case.

Evidence of lateral offset and inconsistent vertical offset is found in many places where the features have not been obliterated by human activities or natural processes. The latest vertical component of offset where the north branch and the main trace cut alluvium, is generally down on the side away from the center-trough ridge. This can be seen just east of the junction of Elizabeth Lake Road and Goode Hill Road where scarps on both the main trace and the north branch face away from the center-trough ridge implying that the alluvial fan has been uplifted between the two fault strands. In contrast, the vertical component where faults cut Tertiary or older rocks is in the opposite sense, with the side away form the center-trough ridge raised. This apparent reversal may simply be due to a large horizontal component of slip.

Offset gullies are the most common feature indicative of recent right-lateral displacement along this stretch. The amount of offset measured in the field is typically 13 to 15 feet (4 to 4.5 meters).

<u>North Branch of the San Andreas fault.</u> In contrast to the main trace, which has been partially obliterated because of more intensive human activities, especially near Elizabeth Lake Road, the surface expression of the north branch is well defined for most of its length by relatively fresh scarps in alluvium.

As is the case with the main trace, the best exposures of the actual fault traces occur in stream cuts along Amargosa Creek. Offset gullies are not evident along the north branch, although one offset channel does occur in a large alluvial fan. Except for the few areas where some right-separation can be seen on hillsides in Tertiary rocks (Anaverde breccia), mainly in the west Leona Valley segment, most of the fault features appear to have been formed by vertical movement with approximately equal vertical and horizontal components and the

possibility that recent movements have been significantly smaller than the movement indicated by offset gullies 13 to 15 feet (4 to 4.5 meters) on the main trace.

The relative freshness of the fault features along the north branch suggest renewed movement in 1857. In terms of surface-rupture potential the north branch should be considered to be as active as the main trace.

7.4 Bouquet Canyon Road is to the right. San Andreas is arrow-straight in this area. The San Francisquito Fault intersects the San Andreas near the mouth of Bouquet Canyon Road.

8.1 Goode Hill Road. Stay straight on Elizabeth Lake Road toward Palmdale.

The area extending for 3300 feet (1 kilometer) east of where Goode Hill Road crosses the north branch of the San Andreas is an excellent place to follow the fault along a series of scarps, closed depressions, and linear ridges.

Located 6 miles (9.6 kilometers) to the west on the shore of Bouquet Canyon Reservoir was the Double Eagle (Gray Eagle) gold mine operated in the 1920's. Production is not known. The ore assayed $8 to $10 a ton (1927 prices). The mine was developed by a 125 foot (38 meters) inclined shaft and a 1200 feet (366 meters) of drifts and crosscuts. A 20 ton stamping mill was active in 1927.

10.1 On the north side of the road at the crest of Portal Ridge was the location of the Red Feather (Amargosa group, La Frentz) manganese mine. Developed during World War I with shallow workings over a 1 to 6 foot (0.3 to 2 meters) wide and 750 foot (229 meters) long lens. A total of 168 tons of production was recorded.

10.9 Ritter Ridge to the left (north) is Pre-Cretaceous Portal Schist Formation. The San Andreas is under the roadway at this point. To the right (south) is Mesozoic or Pre-Cambrian Pelona Schist Formation. Road is in the "Portal Ridge Fault Zone".

11.4 Lazy T Ranch.

Except at Lake Palmdale the only gap in the almost continuous assortment of the fault features is where Anaverde Creek (located to the left (northeast)) flows along the trace. Generally, the fault is buried by stream channel deposits. Unusually heavy streamflow, following intense rains early in 1978, scoured out the alluvial debris from the channel, temporarily revealing the main trace of the San Andreas fault.

The fault was almost perfectly exposed over a distance of 650 feet (200 meters). A ridge-like feature was formed and is composed of clayey gouge that is probably remoblilized Anaverde clay shale extruded along the fault plane. The unusual positive relief of the actual fault plane resulted from the resistance to erosion of the clayey material.

12.1 On the north side of the road on Ritter Ridge was the location of the Black Brothers (Amargosa, Llewellyn Iron) manganese mines. Developed during World War I by an adit and a shaft along a 3 foot (1 meter) wide and 165 foot (50 meters) long traceable manganese quartzite bed. The average grade of ore was 20% per ton. Total production is undetermined.

13.5 White hill on right is Cretaceous Granitic rocks.

13.9 Palmdale city limits. Powerline thrust is on the right (west).

14.9 Stop light. Turn right onto Tierra Subida Avenue.

As a result of the contrast in landforms on opposite sides of the San Andreas fault, structural complexities are revealed on the north and hidden on the south. North of the fault is a ridge or series of ridge or series of ridges in which several large faults and numerous smaller faults are well exposed. South of the fault is a broad lowland that has been receiving alluvial debris for much of Quaternary time. The troughlike lowland is the site of Anaverde Valley and Lake Palmdale.

Offset gullies are particularly abundant just west of the Antelope Valley Freeway. The average right-lateral offset of 10 gullies measured between the Tierra Subida Avenue east to the Antelope Valley Freeway is 12 feet (3.6 meters). The range is 6 to 18 feet (1.8 to 5.5 meters) compared to an average right-lateral offset of 11 feet (3.3 meters) for 18 offset gullies measured from the Freeway east to City Ranch. Although a broad range of offsets occurs along this segment, both the range and the average offset are less than those measured to the west (see discussion of Leona Valley). The amount of the most recent offset along this stretch of the San Andreas fault is about 1 foot (1 meter) less than that measured 9 to 12 miles (15 to 20 kilometers) to the west.

16.2 Rayburn Road.

17.0 Stop sign. Turn left onto Avenue S.

17.5 STOP # 4. ROADCUT ON STATE HIGHWAY 14 AT AVENUE S.
/0.0 RESET ODOMETER.

Park along Avenue S before State Highway 14. Walk up slope on the west side of the fence.

One of the best, most readily accessible exposures of the geology within the San Andreas Fault Zone is provided by the roadcut along the State Highway 14 (Antelope Valley Freeway, Figure 7). The exposure is along a limited-access, divided highway where stopping along the shoulder to view the geology is not permitted.

The San Andreas fault is generally defined as the trace of the most recent surface rupture, which in this area last occurred in conjunction with the great 1857 Fort Tejon earthquake. At the roadcut, the trace of the San Andreas Fault passes beneath the freeway exactly at the southern end of the cut. This location is revealed to passing motorists as a distinct bump in the 50-foot wide zone of freeway pavement, presumably a result of swelling of the clayey gouge beneath the roadbed (Barrows, 1987) or local reverse fault motion due to transpression along the San Andreas Fault.

The roadcut exposes approximately 2400 feet of complexly folded and faulted strata of the Pliocene Anaverde Formation, which has been uplifted between the main trace of the San Andreas Fault Zone and a major splay called the Littlerock Fault. Located approximately 250 feet (76 meters) north of the northern end of the cut, the Littlerock Fault is considered a possible ancestral trace of the San Andreas and has been the site of lateral slip in excess of 13 miles (21 kilometers) since deposition of the Anaverde Formation. Bedrock immediately north of the Littlerock Fault consists of the Mesozoic Holcomb Quartz Monzonite and granodiorite. The sediments are possibly correlative with the Quaternary Harold Formation.

The roadcut can be divided into three zones based on structure and lithology (Smith, 1976). The southern zone, which comprises the souther 600 feet (183 meters) of the roadcut, consists mainly of buff, arkosic sandstone folded into a possible antiformal structure and disrupted by internal faulting. A prominent fault separates the southern zone from the middle zone which consists of an assemblage of intricately synformally folded shale and sandstone that extends for 250 feet (76 meters) to another prominent fault. Thick gouge zones and lithologic discrepancies suggest that the faults bounding the remainder of the cut, the northern zone, consist of alternating, internally faulted, gypsiferous shale and arkose that has been deformed into an asymmetrical synclinal fold.

West half Palmdale (modified Barrows, et el, 1985)

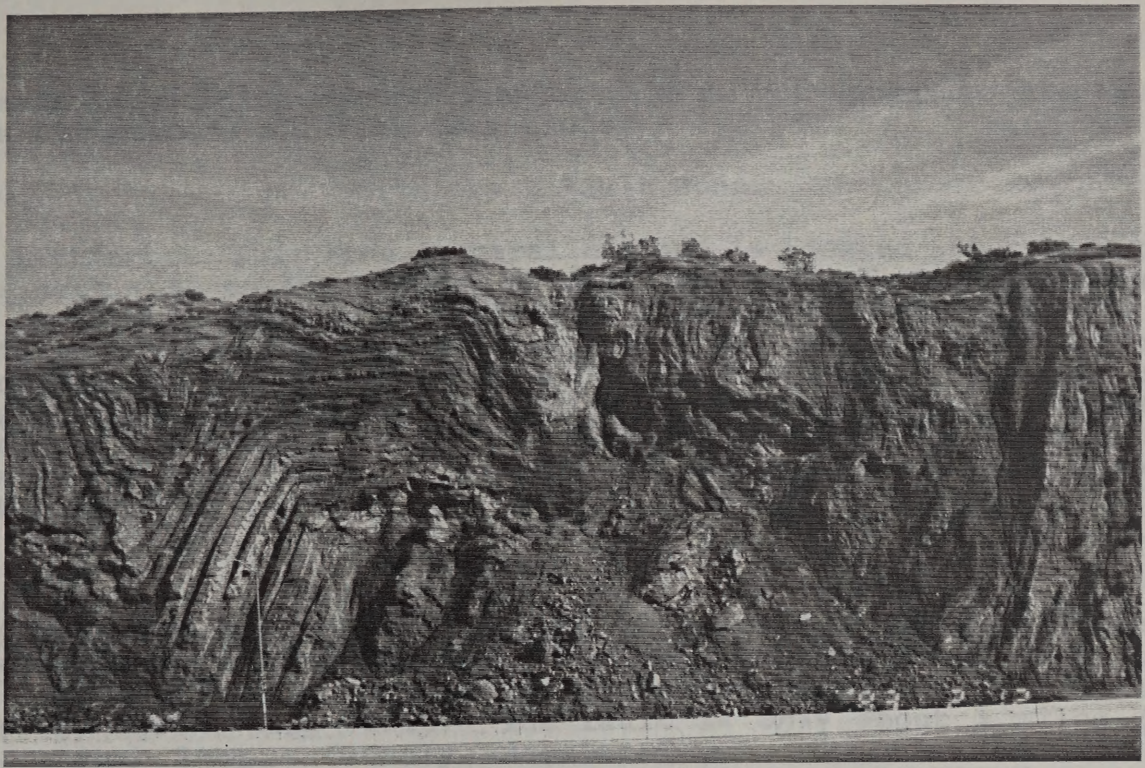


Figure 7. Deformed Hungry Valley Formation in pressure ridge within San Andreas Fault Zone at the Highway 14 roadcut near Palmdale.

In the State Highway 14 roadcut is evidence, within 500 feet (150 meters) of the main trace of the San Andreas fault, of repeated faulting of Quaternary gravels that were deposited upon Anaverde sandstone. Because of the contrasting lithology of the Quaternary Nadeau Gravel, Quaternary Harold Formation, and the buff arkose of the Pliocene Anaverde Formation, different aspects of faulting are distinguishable. Many of the faults appear to be the result of bedding-plane slippage in the steeply dipping sandstone strata.

Because faulting offsets the Quaternary gravels in the Sierra Highway cut, this cut is suitable for comparison of surface expression with the subsurface. Twenty-seven faults are exposed in the roadcut (not including bedding-plane faults in the sandstone that do not affect the gravels); only 6 reach the surface. Only one of the 6 faults was recognizable from topographic evidence. Only a few of the faults in the rocks near the San Andreas fault are mappable from surface evidence. Therefore, trenching is necessary where a more complete assessment of the location and presence of faults is required for evaluating a site prior to construction. This splaying or horsetailing of faults above a major strike-slip fault is called a flower or palm structure and was discovered by oil company geologists.

Looking northerly from the top of the ridge one can see the rapid urbanization encroaching upon the San Andreas, Littlerock, and Cemetery faults. The activity of some of the other faults in the

area is in question because many of them do not appear to displace late Pleistocene alluvial formations.

Littlerock Fault Zone

The Littlerock Fault Zone subparallels and is located about 1476 to 1968 feet (450 to 600 meters) north of the San Andreas. The zone can be traced from Lake Elizabeth Road to Littlerock Wash, a distance of 11 miles (18 kilometers). The zone is a series of discontinuous branching and braided faults with a variety of displacement and recency of activity. Exploratory trenches revealed strike-slip, thrust, normal separations along various segments of the fault. The last activation of the fault was probably during the 1857 event.

Cemetery Fault

Subparallel to both the San Andreas and the Littlerock Faults, the Cemetery Fault is located about 3300 feet (1 kilometer) north of the Littlerock Fault Zone. The fault appears to be a steeply dipping, strike-slip fault. The fault is only about 3 miles (5 kilometers) long. Closely associated with a series of widely spaced discontinuous short faults extends the zone a further 7 miles (11 kilometers) southeasterly from Palmdale to Littlerock Wash. The latest activity was during the Holocene.

Mining Activities

Gypsum

The largest mining operation of gypsum in Los Angeles County was in operation at this site from 1892 to 1915, when the easily mined gypsum was exhausted. Between two companies production of over 10,000 tons of gypsite was mined from the Pliocene Anaverde Formation, northeast of the San Andreas. The Anaverde includes gypsite within nonmarine buff, arkosic sandstone, and dark brown, gypsiferous clay shale. Locally the gyperiferous shale contained 80% to 90% gypsum. The gypsite beds were 2 to 10 feet (0.6 to 3 meters) thick and were mined by open cuts. The material was used for plaster of paris, wall-plaster, and fertilizer.

Acton Gold Mining District

The Acton District also known as the Cedar District is located seven miles southwest of Palmdale in the vicinity of Acton. Placer gold was mined in the San Gabriel Mountains as early as 1834. Lode mining apparently began in the 1870's or 1880's. Production was high until about 1900. A number of mines including the Red Rover, Governor, and Monte Cristo, were active again during the 1930's and early 1940's. The district has been intermittently prospected since, but with very little recorded production.

The deposits consisted of gold-quartz veins in quartz diorite, diorite, gabbro, and schist. The veins are in faulted and fractured zones. The ore is free milling and contains varying amounts of pyrite. The ore bodies commonly consist of small parallel veins rather than a single large vein. The Governor mine was developed to an incline depth of 1000 feet. The mines were the Buena Esperanza, Governor (New York), Helene, Hi-Grade, Red Rover, and Puritan. The highest producers were the Governor with $1.5 million production and the Red Rover with $550,000 production (1970 figures).

0.1 Continue under California Highway 14.

1.1 Stop sign. Turn right (south) onto Sierra Highway. Souther Pacific Railroad tracks are on the right.

To the right of the highway is Lake Palmdale, a man modified sag pond, bordering the fault zone. To the left of the highway is the smaller man modified sag pond, Una Lake, an extension of Lake Palmdale. The zone is on the northeast side of the lakes.

2.0 Turn left onto Barrel Springs Road (gravel road).

East half Palmdale (modified from Barrows et al, 1985)

Due to the abundance of faults of diverse styles scattered across this segment, a geologic map of this segment has the most complex appearance of any area within the fault zone.

The nearly continuous fault traces, or closely parallel fault segments, resulting from the most recent surface ruptures, are defined as the San Andreas fault. This fault is within a zone of branching or subparallel faults exhibiting less continuity but, locally, youthful surface features. The San Andreas fault zone varies in width up to 1300 feet (400 meters) but is commonly less than 650 feet (200 meters) wide.

The disrupted belt of closely spaced, branching splinter faults and subparallel secondary faults is not symmetrical in width on opposite sides of the San Andreas fault. The splinter faults lie largely north of the main trace. The complexity is probably not due to better exposures in the uplifted areas along that side of the fault. Most likely, the complexity results from the overlapping influence of a sympathetic response to movements on the active parts of the Littlerock Fault Zone, which lies only 1650 to 2000 feet (500 to 600 meters) north of the main trace.

Although youthful faulting, implied by the presence of scarps, is widely distributed in this segment, features indicative of lateral faulting are almost exclusively located along the main

trace or on splinter faults within 328 feet (100 meters) of the main trace. One notable exception to this observation occurs along a very youthful-appearing fault scarp in alluvium west of 47th Street East where features due to lateral movement can be seen.

2.1 A south facing scarp is on the left.

2.4 Gravel Pit is on the left. Veer to the right. Road is within the San Andreas Fault Zone.

3.4 An illegal trash dump site is on Bureau of Land Management lands. Future tax dollars will be used to clean this site.

3.5 25th Street East.

3.6 Pearblossom Highway. Continue straight (south) on Barrel Springs Road. San Andreas Fault is 50 yards to the north of the roadway.

4.0 White Hills on right are Pliocene Hungry Valley Formation.

4.1 California Aqueduct.

4.2 Cross California Aqueduct. The gates are equipped with sensors that respond to shaking by breaking an electrical circuit. This causes the gates to close, stopping the flow of water in the aqueduct.

5.3 The bend in road is the location of the San Andreas Fault. The fault scarp is on the left.

5.5 42nd Street.

6.2 47th Street. San Andreas Fault Scarp is on the left.

North Nadeau and South Nadeau (Holmes) Fault Zones

The faults are expressed as a series of discontinuous <u>en echelon</u> and subparallel fault segments about 990 to 3300 feet (0.3 to 1.0 kilometers) southwest of the San Andreas Fault. The fault is traced from 47th Street East (Palmdale) to the San Andreas near Pallett Creek. Both faults vary from vertical to shallow dipping and have right slip movement of 10 miles (16 kilometers).

6.9 Off-set drainages and change in vegetation zones identify the fault zone on the left.

7.2 Stop Sign. Turn right (south) onto Cheezboro Road.

West half Juniper Hills. (modified from Barrows et al., 1985)

San Andreas fault. Except where the fault crosses the broad area with abundant fault features that lie within 0.9 miles (1.5 kilometers) of Littlerock Wash near Mt. Emma Road, the main trace of the San Andreas fault is a simple, continuous feature at the base of ridges or within linear north-facing and south-facing scarps, offset channels, and gullies. Because of its ephemeral nature, many small-scale features, especially fresh-appearing benches and very shallow troughs probably originated or were rejuvenated during the 1857 Fort Tejon earthquake.

The greatest number of well-preserved, small-scale fault features such as closed depressions a few meters across, patches of ponded alluvium, short troughs, and low benches occur between Littlerock Wash and Cheezboro Road. The small size and fresh appearance of the features indicate that forms of disrupted drainage patterns observed along this stretch are offset gullies.

7.7 Turn left onto Emma Road.

7.8 Northern and Southern Nadeau Faults.

12.2 Turn right onto Fort Tejon Road.

12.3 Cross Littlerock Creek.

13.0 Exposure is of folded dark shales of Pleistocene?-Pliocene Juniper Hills Formation.

13.1 Cross San Andreas Fault Zone (beneath thick fill).

13.7 Cross another strand of the Littlerock Creek fault.

13.8 Exposure of Pliocene Anaverde Formation is below the gravels.

14.0 Cross a strand of the Littlerock Creek fault.

14.1 White silts and sands on left are Pliocene Anaverde Formation.

15.6 Stop sign.

17.4 The fault zone is crossed at Highway marker 2477.

17.6 106th Street. The San Andreas Fault is to the left.

20.4 Turn right onto County Road N6 (Longview Road). Continue to the next stop, Devil's Punchbowl Los Angeles County Park.

21.4 Pallett Creek Road.

22.6 Turn left onto Tumbleweed Road (N6). Follow signs to Devil's Punchbowl. Proceeding along this road, the first outcrop is the light-colored granodiorite, the second is the reddish brown Paleocene San Francisquito Formation in the rounded hills, and finally the formations change to the hogbacks of the Miocene Punchbowl Formation.

22.9 Veer to the left onto Devil's Punchbowl Road.

24.7 Punchbowl Formation is to the right.

25.7 STOP #5. DEVIL'S PUNCHBOWL.
/0.0 RESET ODOMETER.

From the parking lot proceed eastward past the visitors center to the vista at the head of the trail leading into the Punchbowl. The immediately striking feature here is the west-northeast plunging, synclinal fold in the conglomerate sandstones of the Punchbowl Formation. Devil's Punchbowl is the type locality of this unit and consists of thick, massive conglomerate arkosic sandstone and interbedded thin layers of greenish to reddish silty mudstone (Dibblee, 1987).

To the east-northeast of the Devil's Punchbowl is Pinyon Ridge. Here the reddish brown marine sediments of the Paleocene San Francisquito Formation lie unconformable on Mesozoic granites and Precambrian(?) gneiss (Dibblee, 1987). The San Andreas Fault Zone lies on the north side of Pinyon Ridge and is out of sight. To the south-southeast are the San Gabriel Mountains which were uplifted along the high angle Punchbowl fault (Dibblee, 1987) that lies at the break in slope between the mountains and alluvial fans. The Punchbowl fault is divided into two strands in this area. The north strand separates dark gray diorite (with white aplitic dikes) basement rock of the San Gabriel Mountains from the Punchbowl Formation. "The south strand is within the basement rocks and forms an alignment of notches" (Dibblee, 1987). Right-lateral and dip-slip motion on the Punchbowl fault causes the northwest-plunging syncline in the Punchbowl Formation (Dibblee, 1987).

The sediments of the Punchbowl Formation were deposited in fluvial and lacustrine environments (Barrows, et al, 1985) and contain mammalian fossils that were determined by Woodburne (1975) to be of Clarendonian and Hemphillian stages. This puts the age of the formation late Miocene to early Pliocene. Because of the striking similarity in lithology with the Cajun Formation (north of the San Andreas Fault Zone) near the intersection of California 138 and Interstate 15, Noble (1954) originally correlated the Punchbowl sediments (south of the San Andreas Fault Zone) with the Cajun Formation. This gave a right-lateral offset to the beds of 25 miles (32 kilometers). However, Woodburne and Golz (1972) discovered middle Miocene mammalian fossils in the Cajun Formation, proving that the late Miocene to early Pliocene Punchbowl

Formation and the Cajun Formation are not correlative and cannot be used to calculate the offset along the San Andreas Fault Zone.

Figure 8. Punchbowl Formation sandstones at Devil's Punchbowl County Park.

Clast-type studies of the Punchbowl Formation (Barrows, et al., 1985) showed that distinctive polka-dot quartz diorite clasts are present in both the Punchbowl Formation and the basal portion of the Ridge Basin Group in Castaic Canyon. The source rocks of the weathered clasts was to the west across the San Andreas Fault and has moved north and away from the Punchbowl area. On this basis, the Punchbowl Formation is correlated with the basal Ridge Basin Group, and this suggests that all of the sediments were originally "deposited (unconformably (meaning a gap of time from Eocene to Miocene (the Oligocene is missing))) on the San Francisquito Formation in the vicinity of the present day Leona Valley near the eastern end of Bouquet Canyon" (Barrows, et al., 1985). The measurement is a 31-mile (50 kilometers), right-lateral offset

along the Punchbowl fault, which is believed to be an ancestral strand of the San Andreas.

A possibility exists that the San Andreas has offset the Punchbowl Formation from the Mill Creek Formation which is exposed 47 miles (75 kilometers) to the southeast of here. Although both units are coeval, as of 1985, not enough petrographic evidence has been found in the Mill Creek Formation to indicate that deposition occurred within the same basin as the Punchbowl Formation (Barrows, et al., 1985).

Return to cars and retrace the route to the intersection of Longview Road (N6) and Pallet Creek Road.

1.0 Miocene Punchbowl Formation is on the left.

2.7 Devil's Punchbowl Road changes to Tumbleweed Road.

3.0 Turn right onto Longview Road (N6).

4.2 Turn right onto Pallet Creek Road.

5.0 STOP #6. PALLETT CREEK SITE.

Located 34 miles (55 kilometers) northeast of downtown Los Angeles, the Pallett Creek trenching location has been a key study in the unravelling of past earthquakes on the San Andreas fault. A major observation of the seismic activity along the Big Bend segment of the fault is the occurrence of major earthquake events (e.g. 1857 Fort Tejon earthquake) occurring between intervals of seismic quiescence. Thus, the paleoseismic record, or the evidence for earthquakes in the geologic record, must be studied to assess the nature of faulting, the length, and regularity of earthquake cycles. The work by Kerry Sieh at Pallett Creek has proven to be a landmark study that has established for the first time the history for multiple earthquakes along a fault based on geologic evidence, and gave Californians a glimpse of the true risk from the "Big One".

Pallett Creek flows northward from the San Gabriel Mountains, crosses the fault and drains into the Mojave desert. The fault has been the focus of deposition of interbedded marsh and stream sediments. Incision of the Pallett Creek gorge in this century has resulted in lowering the groundwater level, draining the sediments and allowing study by trenching. The Holocene sediments exposed in the trenches include well-bedded peat, clay, silt, sand and gravel. At this site, the San Andreas fault trends WNW and is defined by a single active trace. Approximately 1000 feet (300 meters) to the east, the active fault trace steps to the left about 650 feet (200 meters). Exploration of exposures along the gorge indicate that major deformation is confined to the main trace, and that Holocene slippage of other nearby structures is insignificant.

The initial trenching study (Sieh, 1978) consisted of vertical backhoe, bulldozer and shovel trenches oriented at right angles to the fault trace. Vertical deformations that were recorded included scarps and other disruptions along the main trace, secondary faults, and liquefaction phenomena such as sand blows. Upward terminations of faults and sand blows were interpreted as the ground surface at the time of an individual event, the age being bracketed by superadjacent and subjacent peat horizons. Included in the sequence was evidence for the 1857 Fort Tejon earthquake, whose associated level of deformation provided a guide for the assessment of the level of energy for other earthquakes. Nine individual major earthquakes were recorded and dated.

In 1979-1980, Sieh conducted additional trenching studies to better define the horizontal deformation associated with the previously documented paleoearthquakes, to identify older earthquakes, and to collect additional radiocarbon samples to refine the earthquake age estimates. This effort established a new standard for the detailed logging of faulted sediments, by the systematic dissection of a 164 feet (50 meters) long, 49 feet (15 meters) wide and 16 feet (5 meters) deep trench centered along the fault. Individual excavations started with a 6.5 feet (2 meters) wide, 6.5 feet (2 meters) deep, and 66 feet (20 meters) long trench. After logging, the face of the trench was excavated back at 6.5 foot (2 meters) intervals to expose new vertical slices. Also, the trench was deepened an additional 13 feet (4 meters) to expose the sediments underlying the upper sections. Critical sections were logged using vertical exposures spaced less than one meter apart, and locally horizontal surfaces were cleaned and logged.

This detailed work resulted in 130 exposures, forming a three dimensional log of structural and stratigraphic information. Documented features included major and minor faults, fissures, sand blow, anticlines, synclines and variations in the stratigraphic units. In all, 12 major earthquakes and associated structural and sedimentological disruptions were identified. Recently (Sieh, Stuiver, and Brillinger, 1989), the peat units were resampled for radiocarbon dating using large proportional counters, conducted at the Seattle Quaternary Isotope Laboratory, resulting in error limits of less than 23 calendar years for peat deposits bracketing the last 10 identified earthquake events.

A major contribution of this effort has been the definition of the earthquake cycle along proximal sections of the San Andreas fault. The average recurrence interval for the last 10 major earthquakes is estimated at 132 years, assuming that the earthquake horizons identified in the logs are not representative of two events separated by only a few years. The recent more precise dating study has identified temporal clusters of two or three events. The earthquakes within the clusters are separated by periods of several decades, and clusters are separated by dormant periods of two or three centuries. Assuming that the pattern is truly representative

of the fault activity, the current period of dormancy may be greater than two centuries. Sieh, Stuiver and Brillinger (1989) calculated a 22% estimated probability of major fault rupture in thirty years at Pallet Creek using the more precise dates, but the uncertainty in the probability estimate is large.

To the south, at Cajun Pass, recent drilling to depths greater than 20,000 feet have led to evidence that in that area the San Andreas Fault Zone forces are primarily compressive. This means a change has occurred in plate vector from nearly pure right-lateral strike-slip, where slices of the North American Plate were added to the Pacific Plate and then began moving northwestward; to a more collisional type compressive plate interaction. The motions of transform and compressive are termed tranpressive. Most people don't realize that southern California is in one of the most active mountain building events (or orgenies) due to increasing compression between the Pacific and North American Plates.

END OF THE FIELD TRIP

To return to Palmdale follow the roads back to Fort Tejon Road. Turn right at 131st Street. This street intersects Pearblossom Highway. A left turn goes to Palmdale. A right turn goes towards the Cajun Pass.

TABLE 4. LITHOLOGIC DESCRIPTION

Pleistocene Formations

Upper Pleistocene Nadeau Gravel-a sedimentary nonmarine gravel.

Late Pleistocene Harold Formation-a sedimentary nonmarine rock composed of sediments derived from the Late Pleistocene-Pliocene Juniper Hills Formation and the Mesozoic or Pre-Cretaceous Pelona Schist.

Late Pleistocene-Pliocene Juniper Hills Formation-a sedimentary nonmarine undifferentiated pebbly arkosic sandstone.

Pliocene Formations

Pliocene Anaverde Formation-a sedimentary nonmarine arkosic sandstone and gypsiferous shale.

Pliocene Hungry Valley Formation-a sedimentary terrestrial sand, shale, and clay.

Pliocene Santa Margarita Formation-a sedimentary nonmarine sandstone.

Miocene Formations

Miocene Neenach Volcanic Formation-See Neenach Volcanic Section

Miocene Pinnacles Volcanic Formation-See Neenach Volcanic Section

Miocene Punchbowl Formation-See Devil's Punchbowl Section

Oligocene Formations

Olig-Miocene Tecuya Formation-a sedimentary terrestrial sediment of red, green, and gray sandstone, conglomerate, and clay.

Paleocene Formations

Paleocene San Francisquito Formation-a marine, hard, light buff, cobblely, arkosic sandstone and thin interbeds of dark gray, micaceous shale.

Cretaceous Formations

Cretaceous Lebec Quartz Monzonite-a coarse grained, high in felsic mineral, containing small K-feldspar phenocrysts and rounded bluish quartz, with fine grained facies shown by a dotted pattern.

Cretaceous Tejon Lookout Granite-a coarse grained, high in felsic mineral, igneous rock.

Pre-Cretaceous Formations

Pre-Cretaceous Portal Schist-a metamorphic, medium grained, prominently foliated schist.

Mesozoic or Pre-Cambrian Pelona Schist-a metamorphic, blue-gray where fresh, but weathers brown, medium grained, prominently foliated, silvery sheen schist.

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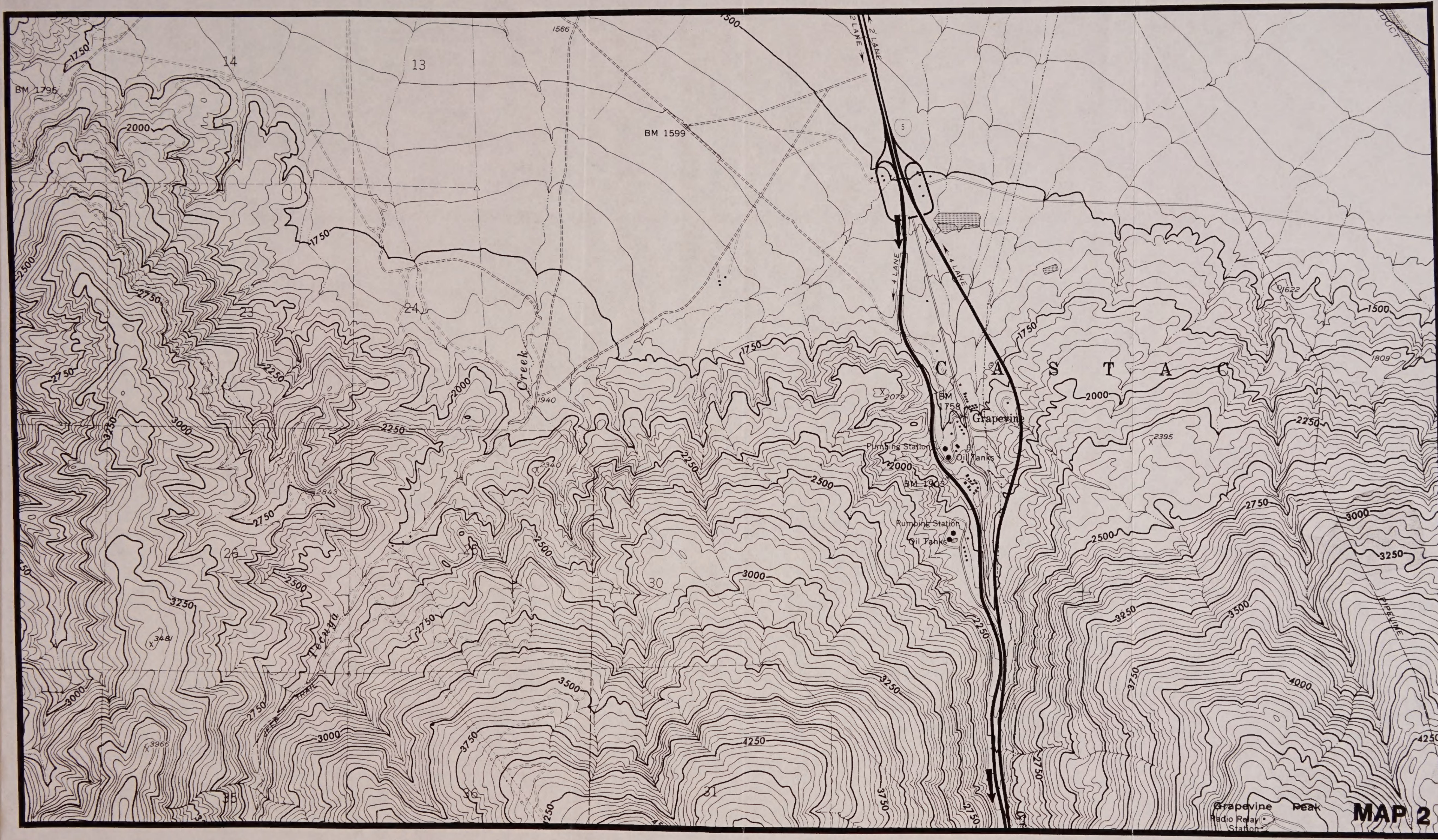
TEJON OIL FIELD
Oil Tanks
Mile 282
35
36
BM 1142
R 19 W
R 20 W
2 LANE
2 LANE
31
BM 1058
Oil Tanks
1000
32
OIL WELLS
33
BM 1016
Oil Tanks
BM 1095
BM 1089
1040
1346
1219
1217
1136
1105
1250
CALIFORNIA
Siphon
AQUEDUCT
2
Creek
1
Creek
Mile 285
6
5
Creek
4
1500
Oil Wells
1250
BM 1265
1430
1381
1302
1263
1204
Siphon
Rose Station (Site)
BM 1259
1500
BM 1467
11
12
7
8
9
PIPELINE
CALIFORNIA
Tecuya
Salt
Weighing Station
Grapevine
BM 1390
1718
1524
1497
Rose Stage Station Historical Marker
TRAIL

MAP 1



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1566
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2 LANE
2 LANE
5
BM 1599
DUCT
1750
2000
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24
4 LANE
4 LANE
1622
1500
1750
1809
2750
2250
1750
Creek
1940
C A S T A C
2079
BM 1758
Grapevine
2000
2000
3250
3000
2250
2250
2395
Pumping Station
Oil Tanks
2340
2000
2250
2843
BM 1903
2500
2750
2750
3000
26
25
2500
Pumping Station
Oil Tanks
2500
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3250
3250
Tecuya
2750
2250
3250
3500
3481
JEEP TRAIL
3000
2750
3500
3250
3750
4000
PIPELINE
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4250
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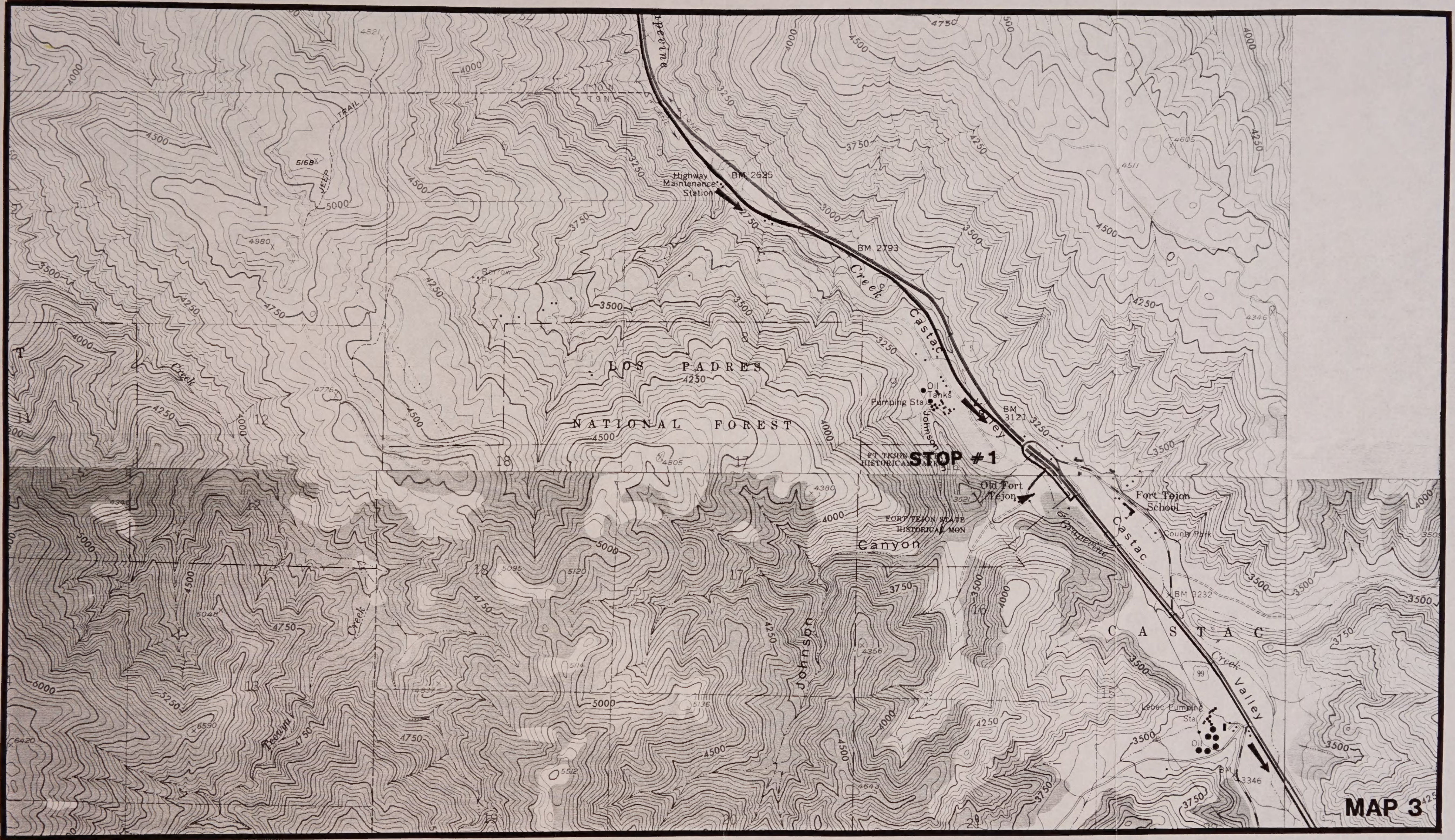
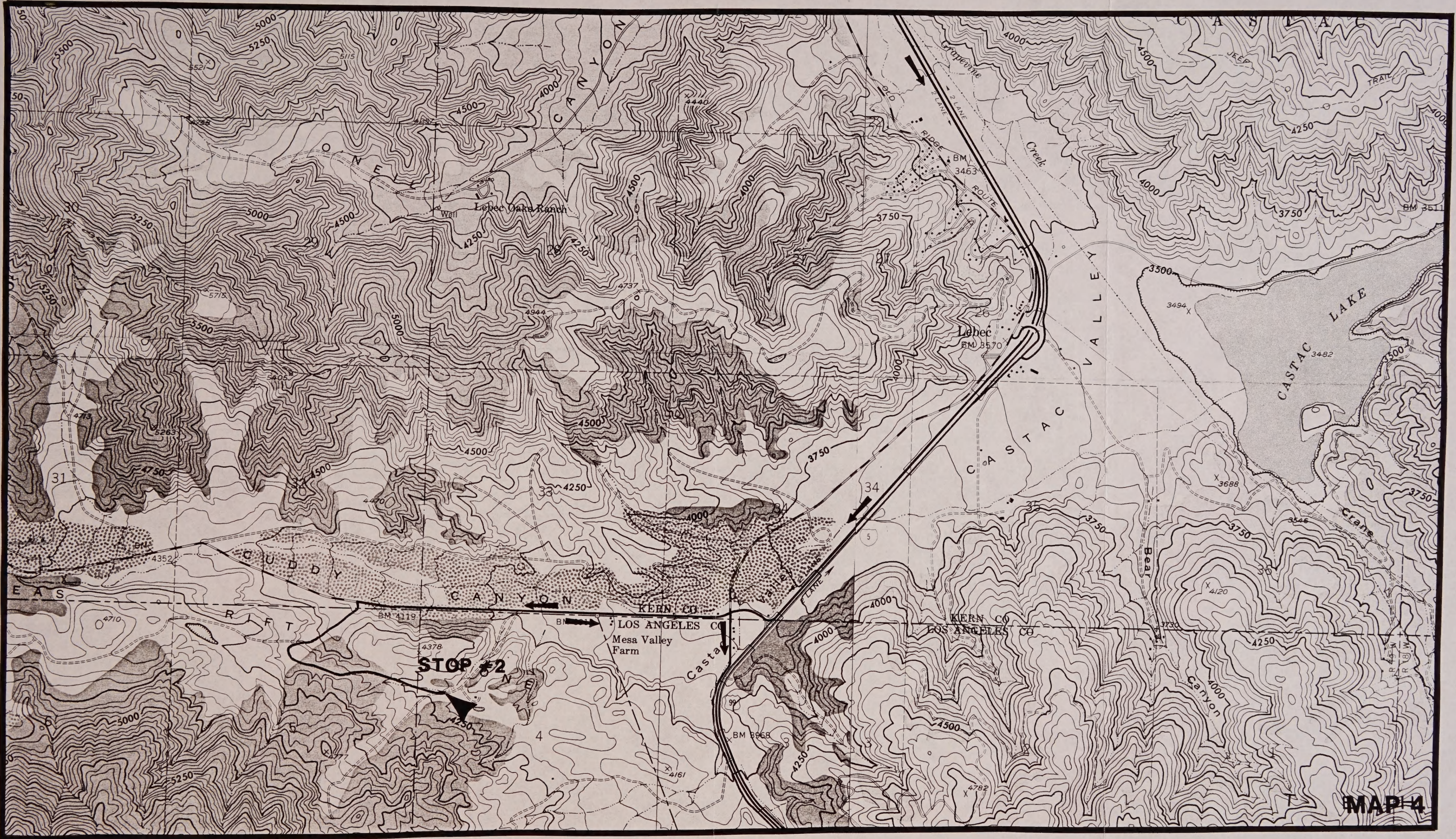
31
3750
2750
2250
Grapevine Peak
Radio Relay Station

MAP 2


Highway Maintenance Station
BM 2625
BM 2793
Castac Creek
Borrow Pit
LOS PADRES
NATIONAL FOREST
Oil Tanks
Pumping Sta
Johnson
BM 3121
Valley
FT TEJON HISTORICAL
STOP #1
Old Fort Tejon
FORT TEJON STATE HISTORICAL MON
Canyon
Grapevine
Fort Tejon School
County Park
BM 3232
CASTAC
Castac Valley
Creek
Lebec Pumping Sta
Oil
BM 3346
99
Johnson
Tecuya Creek
T10N
T9N
JEEP TRAIL
MAP 3


STOP #2
MAP 4
Lebec Oaks Ranch
Well
Lebec
BM 3570
BM 3463
BM 3511
BM 4119
BM 3968
4352
CASTAC LAKE
CASTAC VALLEY
CASTAC
CUDDY CANYON
KERN CO.
LOS ANGELES CO.
Mesa Valley Farm
Castac
Grapevine
Creek
OLD RIDGE ROUTE
2 LANE
JEEP TRAIL
Bear Canyon
Crane
3500
3750
4000
4250
4500
5000
5250
5500
3494
3482
3688
4120
4782
4161
4378
4710
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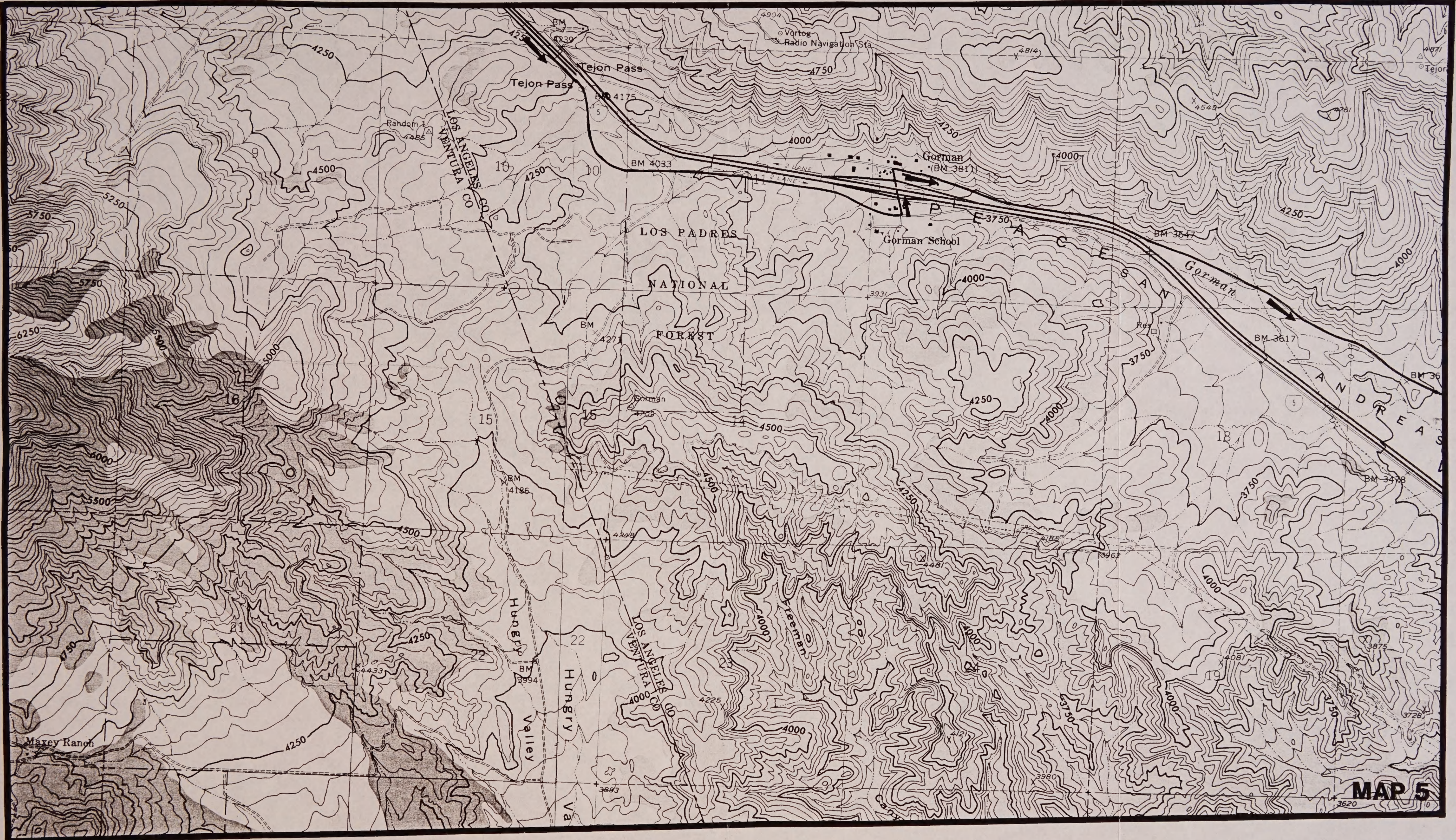

Tejon Pass
Tejon Pass
BM 4239
BM 4175
Vortac Radio Navigation Sta.
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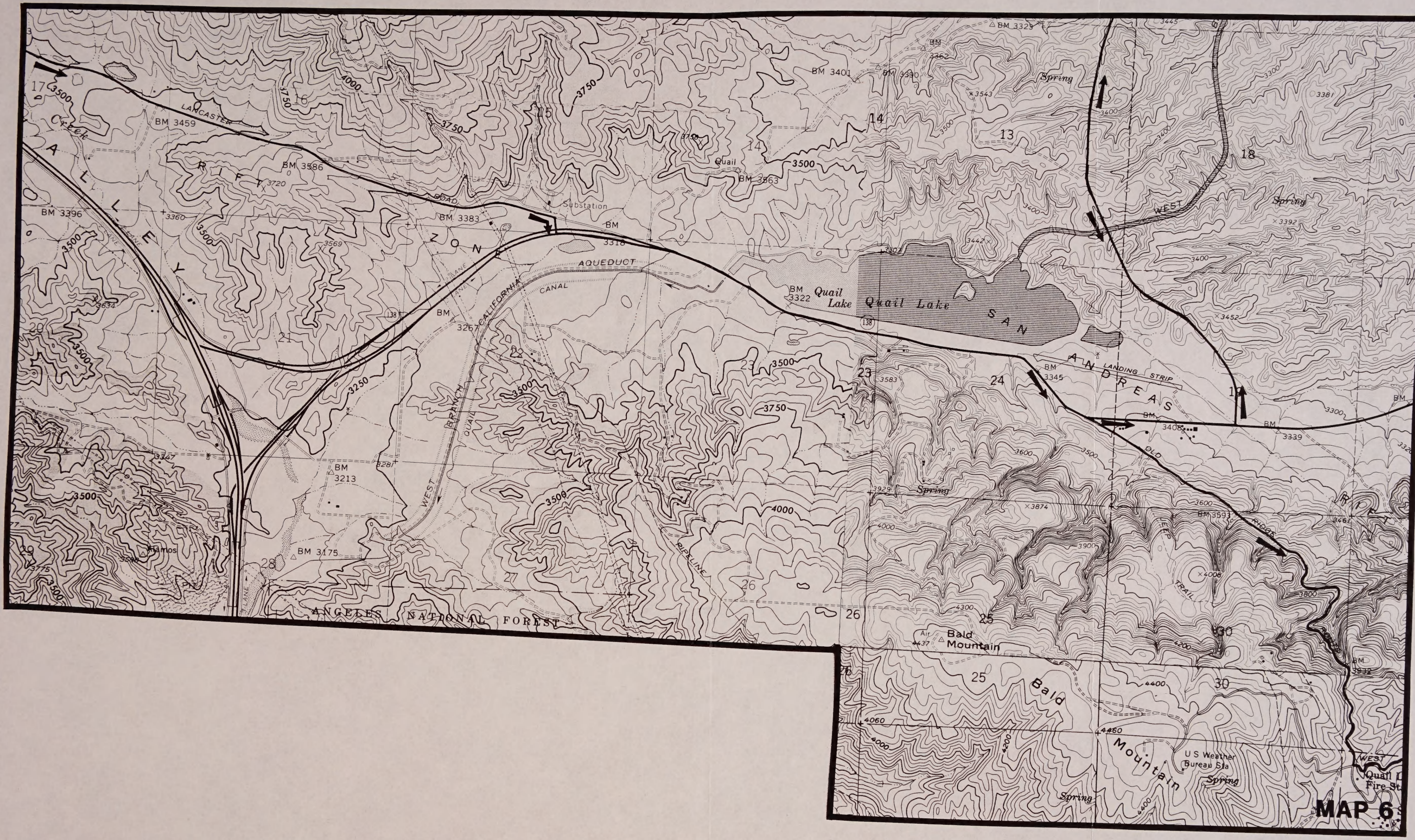
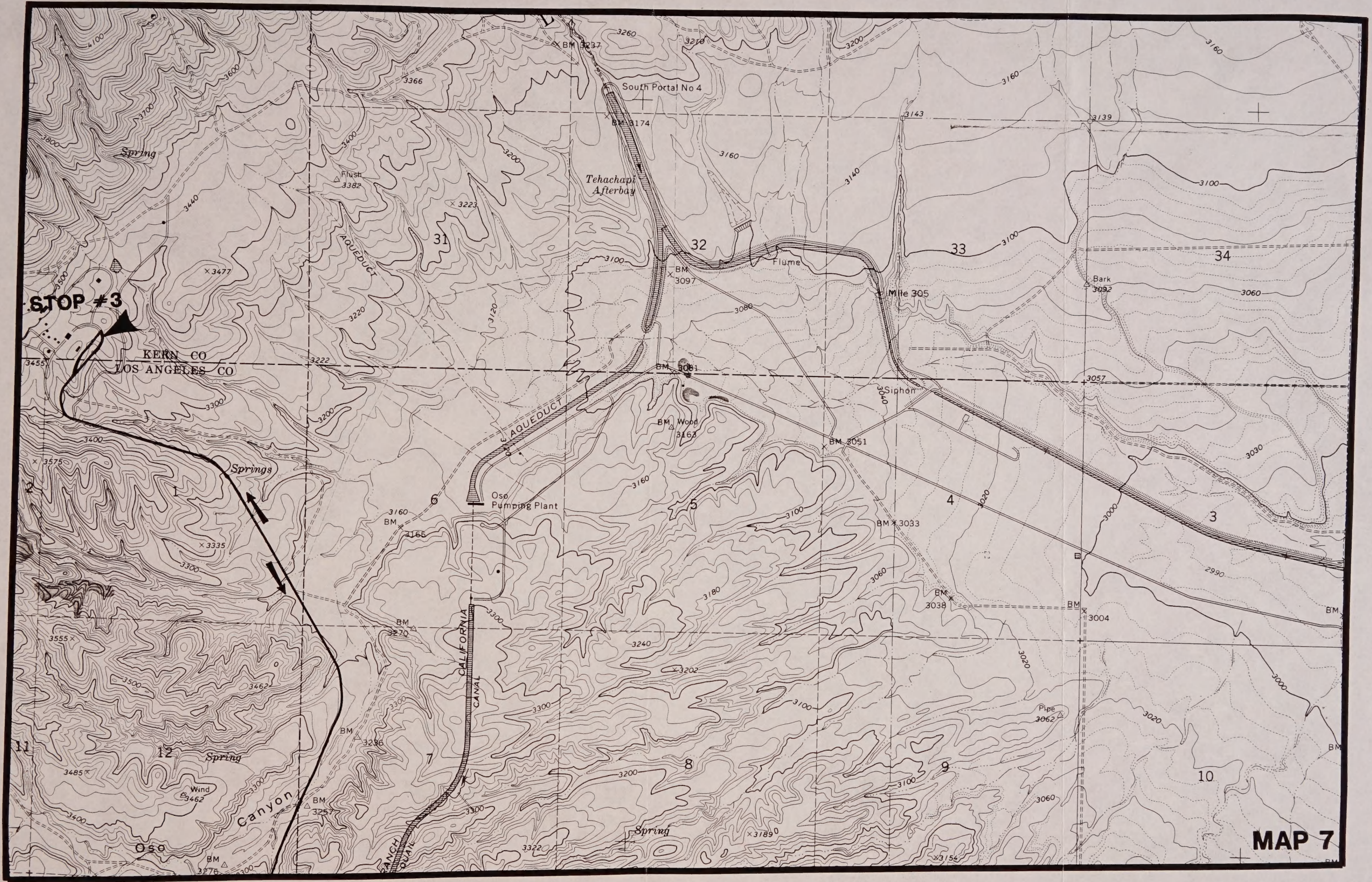
4871
Tejon
4545
Random 1
4485
LOS ANGELES CO
VENTURA CO
BM 4033
Gorman
(BM 3811)
Gorman School
LOS PADRES
NATIONAL
FOREST
SAN ANDREAS
Gorman
BM 3647
BM 3617
BM 3478
Res
3931
BM 4271
Gorman 4709
BM 4186
4448
4185
3963
4481
Freeman
Hungry
Hungry
Valley
Hungry Valley
BM 3994
4433
4225
4121
3980
3893
3875
3728
3620
4081
Maxey Ranch
LOS ANGELES CO
VENTURA CO
4250
4500
4750
5250
5750
6250
5500
5000
6000
4000
3750
MAP 5

MAP 5

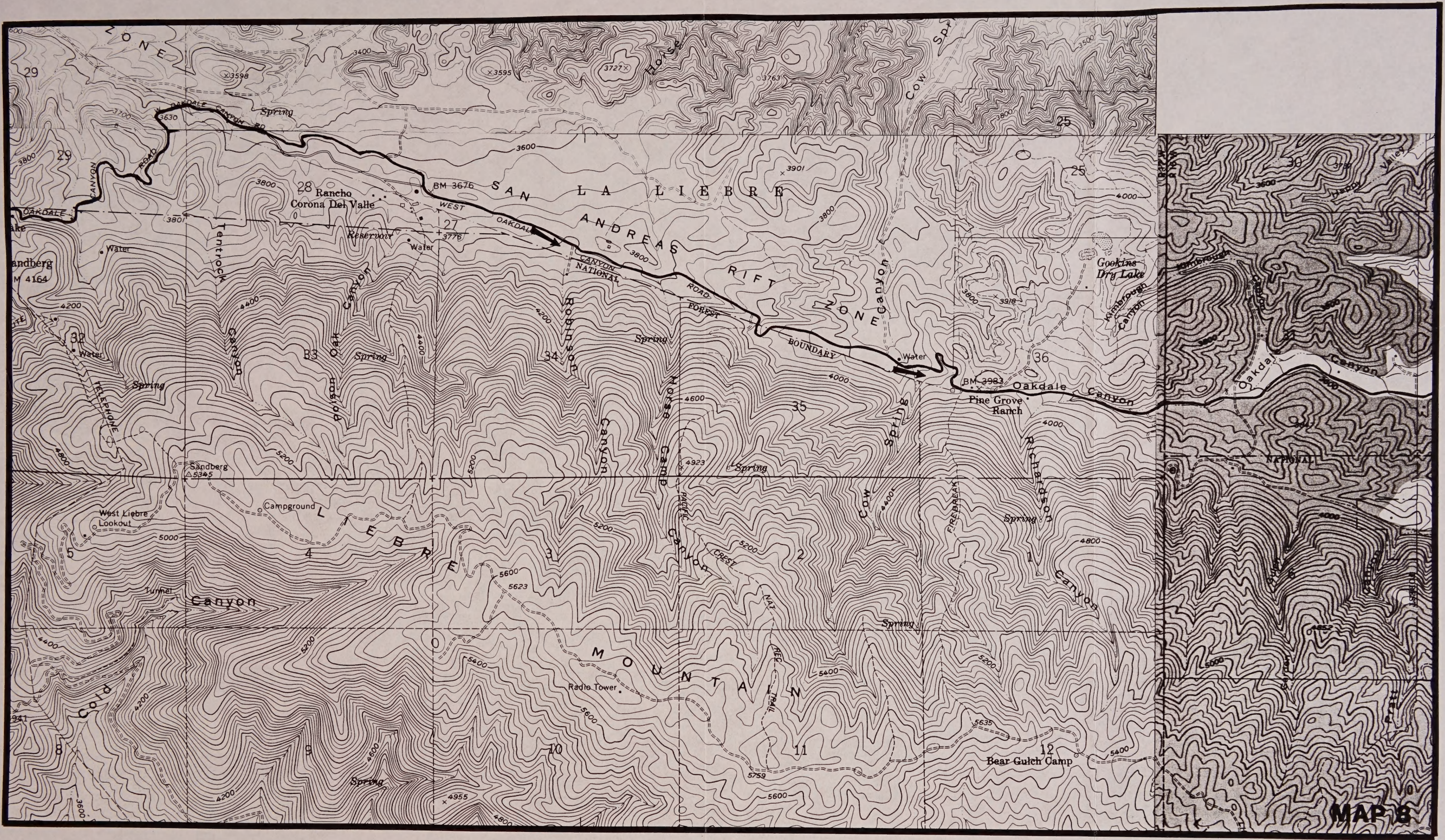

LANCASTER ROAD
RIFT ZONE
VALLEY
Creek
BM 3459
BM 3586
BM 3396
BM 3383
BM 3318
Substation
Quail
BM 3563
BM 3401
BM 3390
BM 3362
BM 3329
Spring
CALIFORNIA AQUEDUCT
CANAL
WEST BRANCH
BM 3267
BM 3213
BM 3175
BM 3322
Quail Lake
Quail Lake
SAN ANDREAS
LANDING STRIP
BM 3345
BM 3408
BM 3339
WEST
OLD RIDGE ROUTE
PIPELINE
JEEP TRAIL
BM 3593
Bald Mountain
Bald Mountain
U S Weather Bureau Sta
ANGELES NATIONAL FOREST
Quail L
Fire St
138
3500
3750
4000
3250

MAP 6

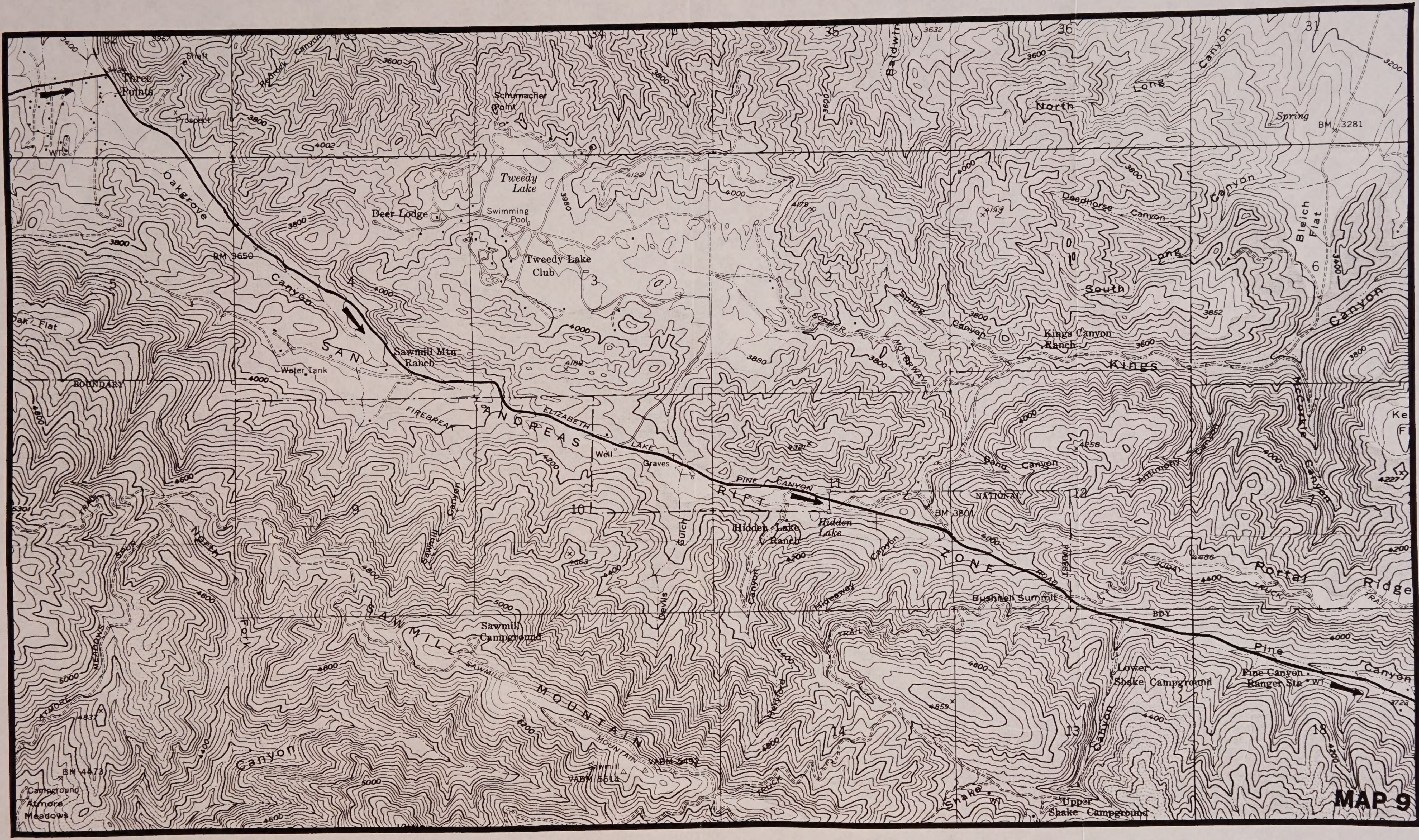


STOP #3
KERN CO
LOS ANGELES CO
South Portal No 4
Tehachapi Afterbay
AQUEDUCT
Flume
Mile 305
Siphon
Oso Pumping Plant
CALIFORNIA CANAL
QUAIL RANCH
Springs
Spring
Canyon
Oso
Flush 3382
Wood 3163
Bark 3092
Pipe 3062
Wind 3462
31
32
33
34
1
2
3
4
5
6
7
8
9
10
11
12

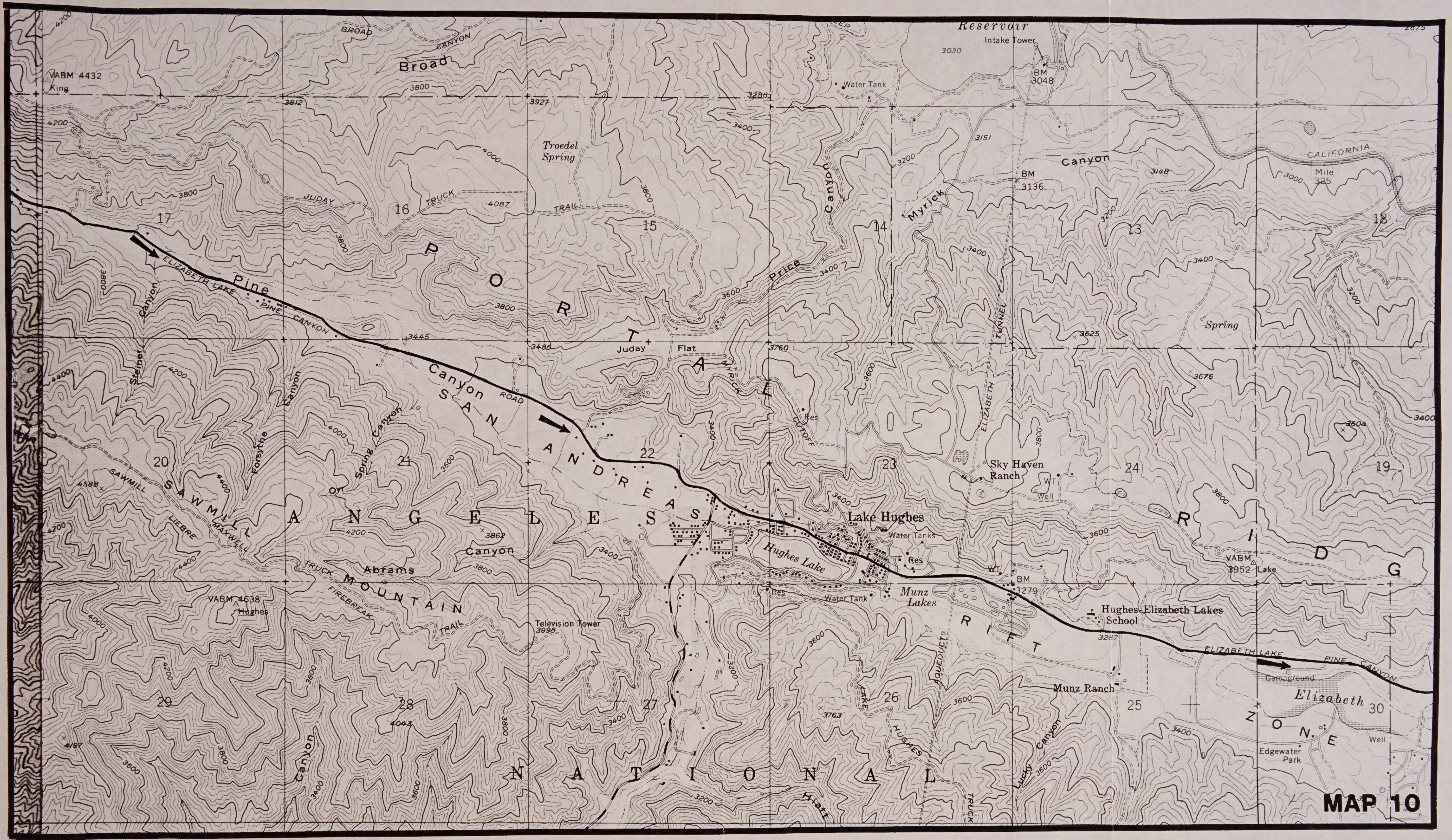
MAP 7


SAN ANDREAS RIFT ZONE
LA LIEBRE
LIEBRE MOUNTAIN
OAKDALE CANYON RD
Rancho Corona Del Valle
BM 3676
Reservoir
Water
Spring
Tentrock Canyon
Pod Canyon
Robinson Canyon
Horse Camp Canyon
Cow Spring Canyon
Richardson Canyon
Kimbrough Canyon
Gookins Dry Lake
BM 3983
Oakdale Canyon
Pine Grove Ranch
NATIONAL FOREST BOUNDARY
Sandberg
BM 4164
Sandberg 5345
West Liebre Lookout
Campground
Tunnel
Canyon
Cold
TELEPHONE
PACIFIC CREST NAT REC TRAIL
FIREBREAK
Radio Tower
Bear Gulch Camp
5623
5635
5759
4923
4955
3598
3595
3727
3763
3901
3918
3630
3776
Horse
Cow
Valley

MAP 8

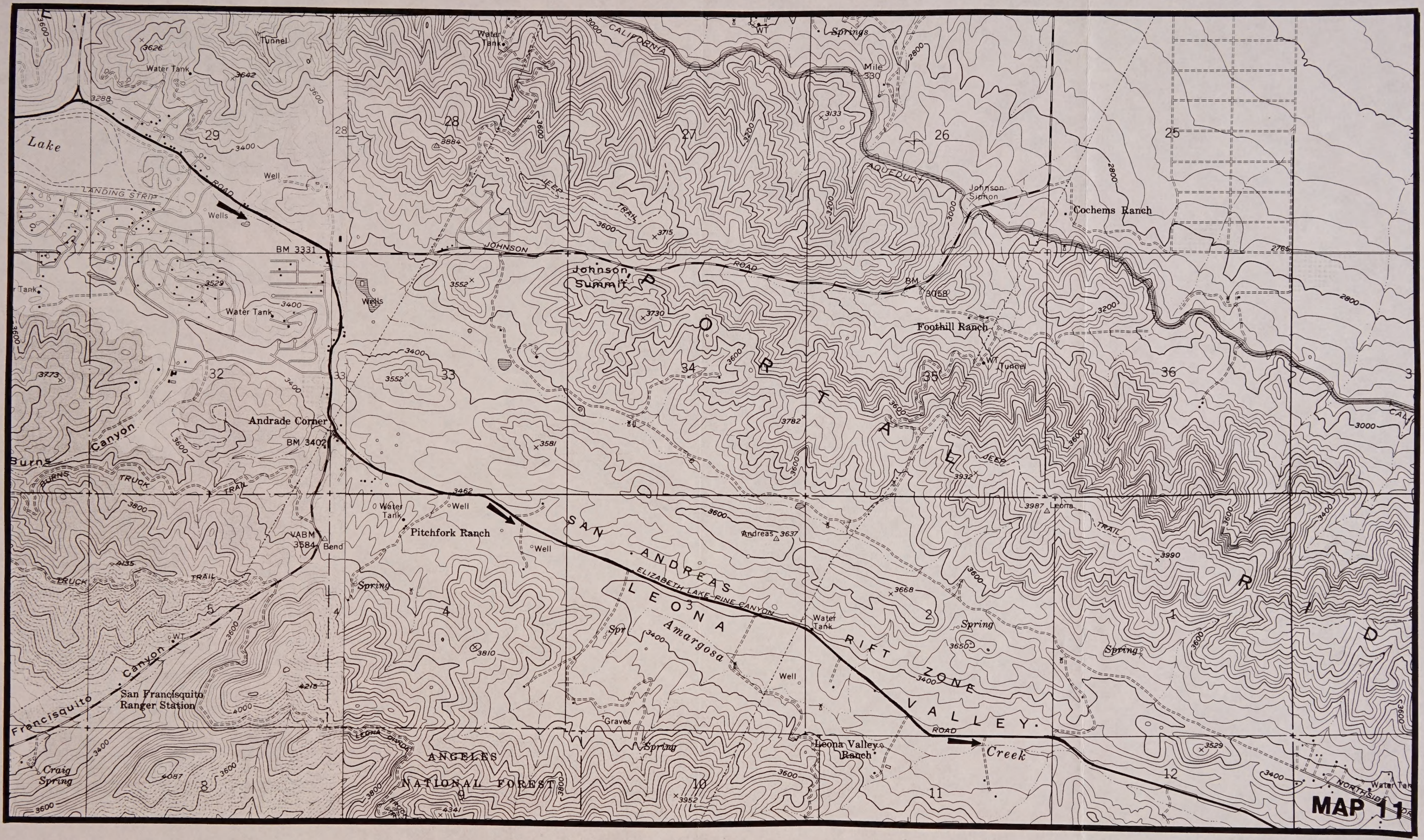

Three Points
Shaft
Prospect
Oakgrove Canyon
BM 3650
Oak Flat
BOUNDARY
Water Tank
Sawmill Mtn Ranch
Schumacher Point
Tweedy Lake
Deer Lodge
Swimming Pool
Tweedy Lake Club
SAN ANDREAS RIFT ZONE
FIREBREAK
ELIZABETH LAKE PINE CANYON ROAD
Well
Graves
Hidden Lake Ranch
Hidden Lake
Baldwin
North Long Canyon
South Long Canyon
Spring
BM 3281
Deadhorse Canyon
Bleich Flat
Kings Canyon
Kings Canyon Ranch
Spring Canyon
SORBER MOTORWAY
Sand Canyon
Antimony Canyon
McConkie Canyon
NATIONAL
BM 3801
Bushnell Summit
Portal Ridge
JUDAY TRUCK TRAIL
BDY
Pine Canyon
Pine Canyon Ranger Sta
Lower Shake Campground
Upper Shake Campground
Shake
Sawmill Campground
SAWMILL MOUNTAIN
Sawmill
VABM 5492
VABM 5614
Devils Gulch
Hideaway Canyon
Burnt Canyon
North Fork
Atmore Canyon
MEADOWS TRAIL
BM 4473
Campground
Atmore Meadows
TRAIL
TRUCK
4000
3800
3600
4200
4400
4600
4800
5000
5200

MAP 9

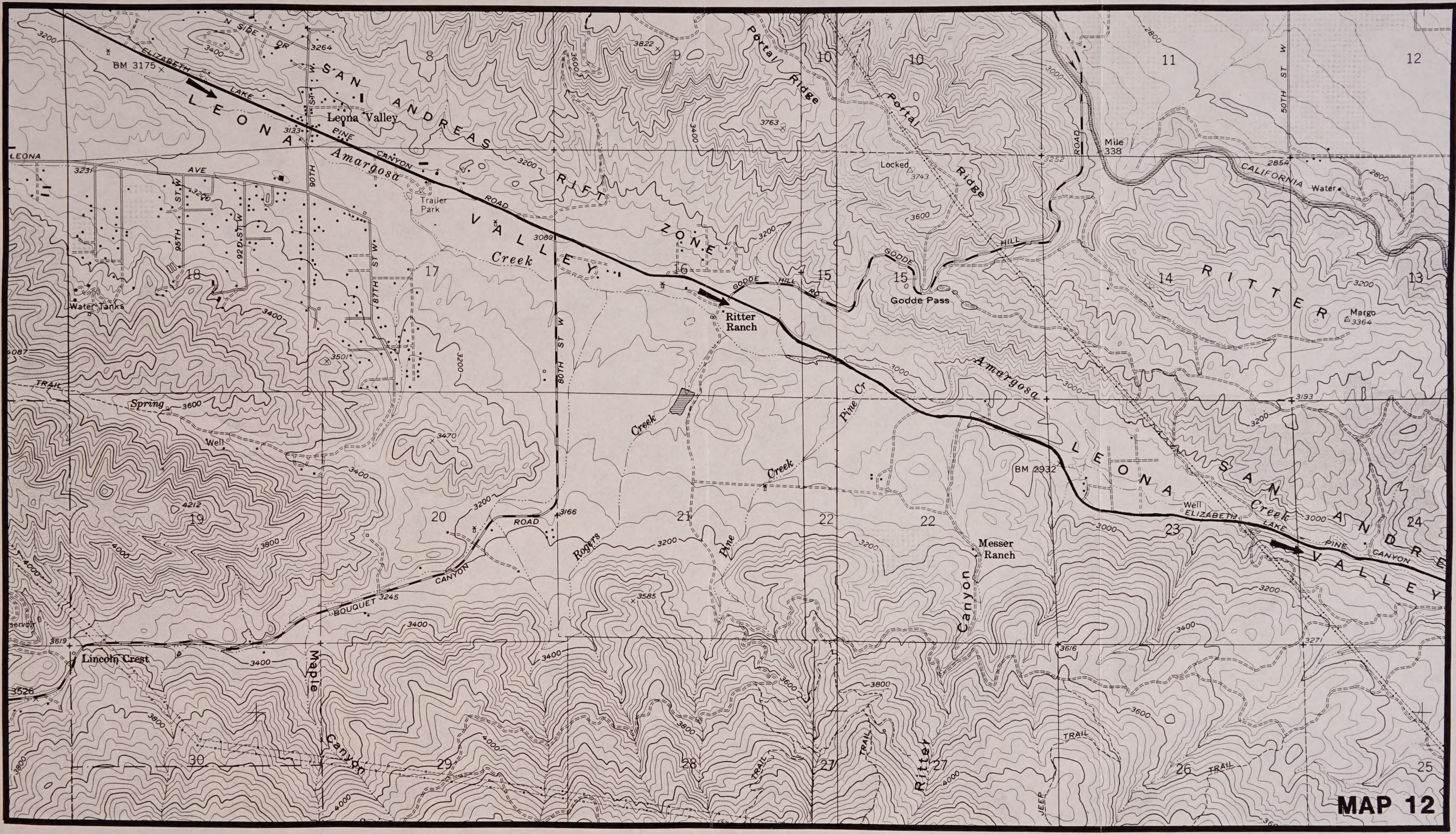


Reservoir
Intake Tower
BM 3048
Water Tank
Broad Canyon
VABM 4432 King
Troedel Spring
Juday Truck Trail
Price Canyon
Myrick Canyon
Canyon
BM 3136
California Aqueduct
Mile 325
Spring
Elizabeth Lake Pine Canyon
Pine Canyon Road
Steiner Canyon
Forsythe Canyon
Spring Canyon
P O R T A L R I D G E
Juday Flat
Myrick Cutoff
Elizabeth Tunnel
Sky Haven Ranch
WT
Well
Res
S A N A N D R E A S R I F T Z O N E
Lake Hughes
Water Tanks
Hughes Lake
Munz Lakes
Water Tank
BM 3279
VABM 3952 Lake
Hughes-Elizabeth Lakes School
Munz Ranch
Campground
Elizabeth
Edgewater Park
Well
Sawmill Liebre Maxwell Truck Trail
Sawmill Mountain Firebreak
Abrams Canyon
VABM 4638 Hughes
Television Tower 3998
A N G E L E S N A T I O N A L
Lake Hughes Truck Trail
Aqueduct
Hiatt
Lucky Canyon
Canyon
17
16
15
14
13
18
20
21
22
23
24
19
29
28
27
26
25
30

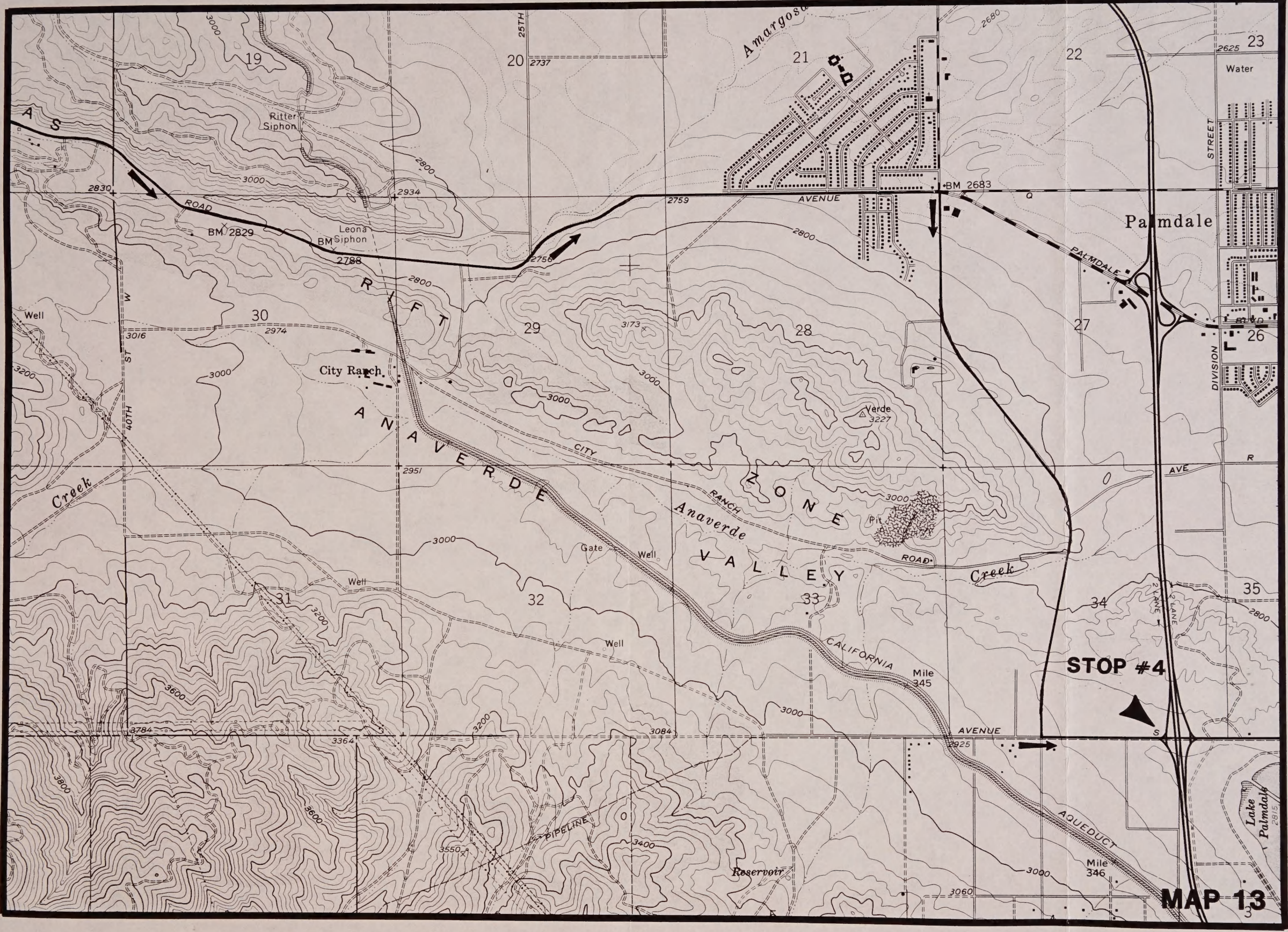
MAP 10


Lake
LANDING STRIP
ROAD
Tunnel
Water Tank
Well
Wells
BM 3331
Water Tank
Andrade Corner
BM 3402
Burns
Canyon
BURNS TRUCK TRAIL
VABM 3584
Bend
Francisquito
Canyon
San Francisquito Ranger Station
Craig Spring
WT
JEEP TRAIL
JOHNSON ROAD
Johnson Summit
CALIFORNIA AQUEDUCT
Springs
Mile 330
Johnson Siphon
Cochems Ranch
BM 3058
Foothill Ranch
WT
Tunnel
PORTAL RIDGE
Pitchfork Ranch
Water Tank
Well
Spring
SAN ANDREAS RIFT ZONE
ELIZABETH LAKE-PINE CANYON ROAD
LEONA VALLEY
Amargosa
Spr
Andreas
Leona
Water Tank
Spring
Well
Graves
Spring
Leona Valley Ranch
Creek
ANGELES NATIONAL FOREST
LEONA DIVIDE
NORTHSIDE
Water Tank
28
29
27
26
25
32
33
34
35
36
5
4
3
2
1
8
9
10
11
12
3626
3642
3288
3400
3600
3884
3715
3133
2800
3200
3000
2765
3552
3529
3730
3782
3773
3581
3462
3932
3987
3990
3637
3668
3650
3810
3952
4135
4215
4087
4341
3529

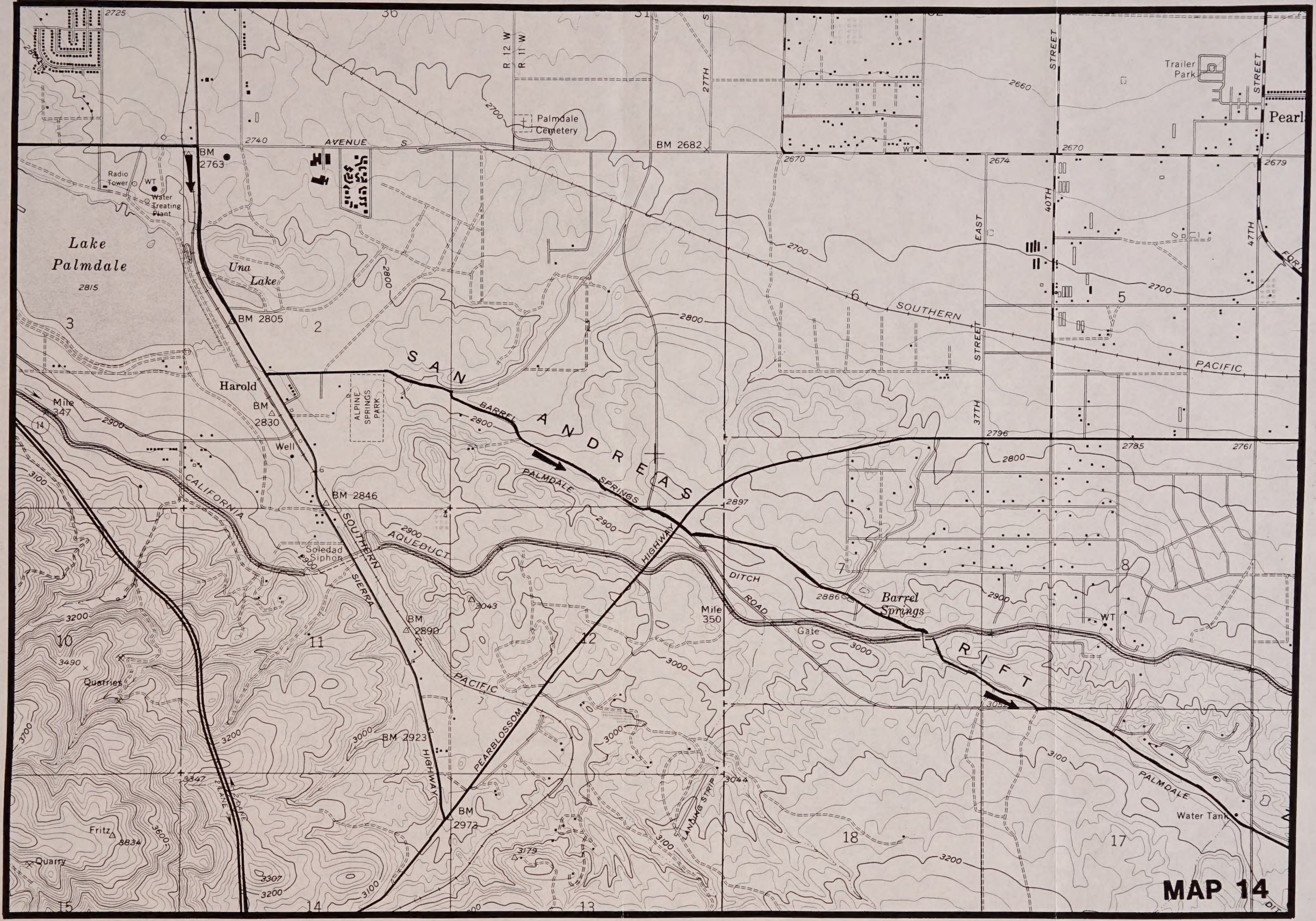
MAP 11


SAN ANDREAS RIFT ZONE
LEONA VALLEY
Leona Valley
Amargosa Creek
Ritter Ranch
Godde Pass
Portal Ridge
RITTER
Messer Ranch
Lincoln Crest
Maple Canyon
Ritter Canyon
Rogers Creek
Pine Creek
Pine Cr
ELIZABETH LAKE PINE CANYON ROAD
BOUQUET CANYON ROAD
GODDE HILL RD
CALIFORNIA
Water Tanks
Trailer Park
Spring
Well
Locked 3743
Margo 3364
Mile 338
BM 3175
BM 2932
80TH ST W
87TH ST W
90TH ST W
92D ST W
95TH ST W
50TH ST W
AVE
LEONA
TRAIL
JEEP
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

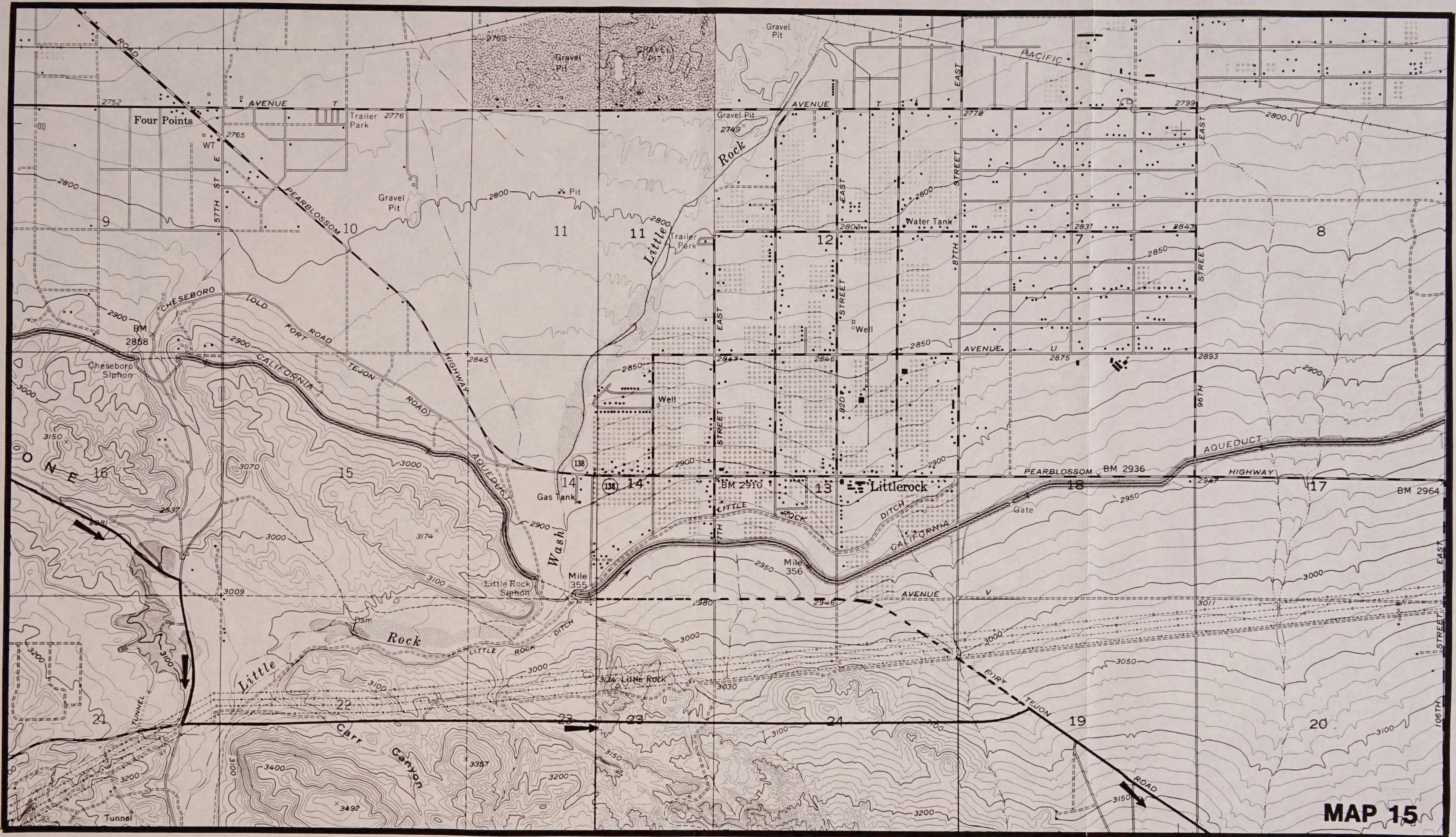
MAP 12


STOP #4
19
20
21
22
23
25TH
Amargosa
2737
2680
2625
Water
Ritter Siphon
Leona Siphon
BM 2829
BM
2788
2830
2934
2800
3000
ROAD
2759
AVENUE
BM 2683
Q
STREET
Palmdale
PALMDALE
BLVD
26
DIVISION
2756
RIFT
Well
30
2974
3016
W
40TH
ST
City Ranch
29
3173
28
27
3200
Verde
3227
ANAVERDE
CITY
RANCH
ZONE
Anaverde
VALLEY
Pit
ROAD
Creek
2951
AVE
R
Gate
Well
31
32
33
34
35
3200
2 LANE
CALIFORNIA
Mile 345
3600
3784
3364
3084
AVENUE
2925
S
3800
3550
PIPELINE
3400
Reservoir
AQUEDUCT
Mile 346
3060
Lake Palmdale
2815

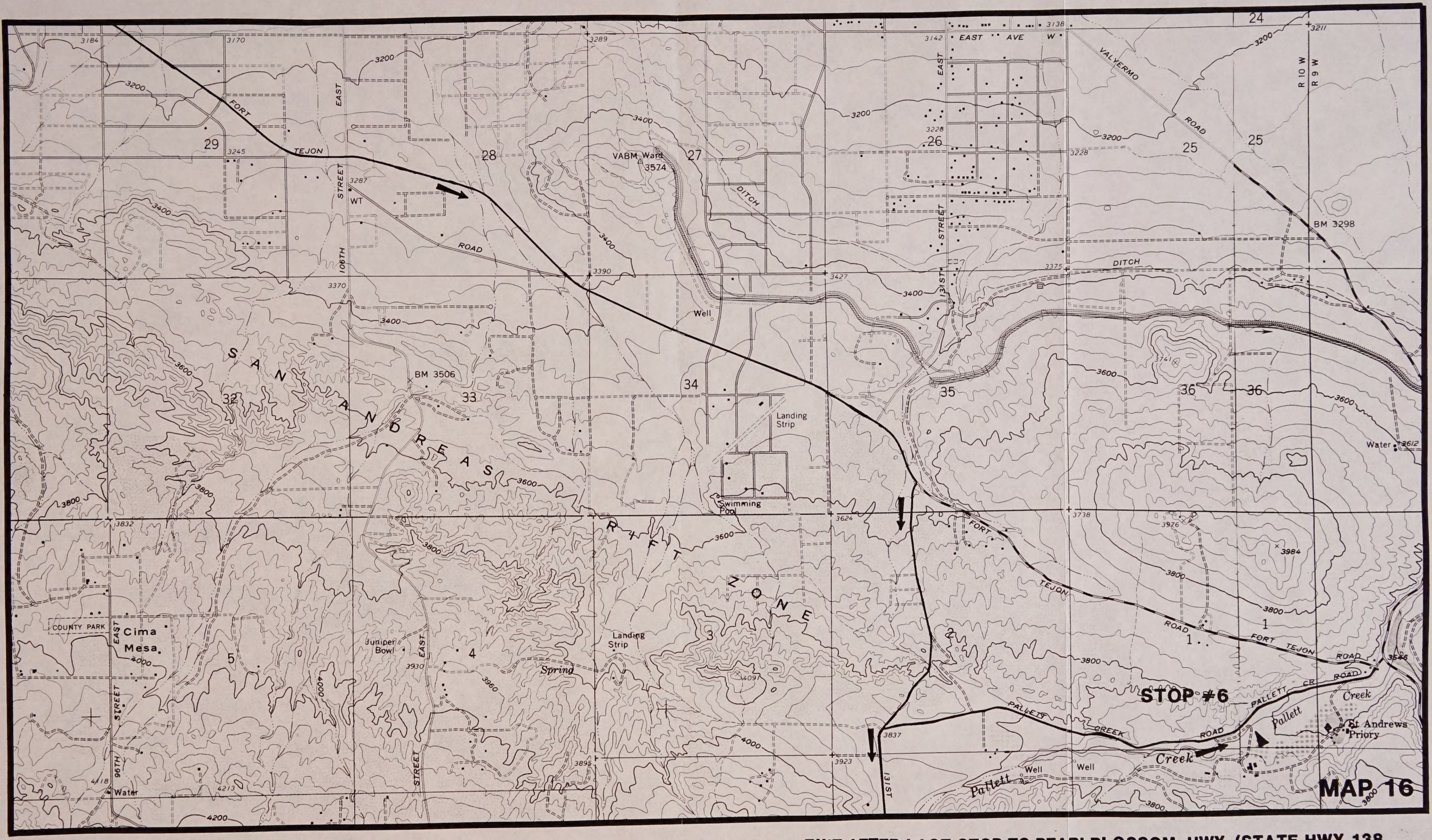
MAP 13


SAN ANDREAS
RIFT
Lake Palmdale
2815
Una Lake
Harold
Radio Tower
WT
Water Treating Plant
BM 2763
BM 2805
BM 2830
BM 2846
BM 2890
BM 2923
BM 2973
BM 2682
Well
Mile 347
Mile 350
14
CALIFORNIA AQUEDUCT
Soledad Siphon
SOUTHERN PACIFIC
SIERRA HIGHWAY
PEARBLOSSOM HIGHWAY
BARREL SPRINGS
PALMDALE DITCH ROAD
Barrel Springs
ALPINE SPRINGS PARK
Palmdale Cemetery
AVENUE S
R 12 W
R 11 W
27TH
37TH STREET
EAST
40TH STREET
47TH STREET
Trailer Park
Pearl
Quarries
Quarry
Fritz
3834
3490
3347
3179
3043
3044
3052
2897
2886
2796
2785
2761
2725
2740
2670
2674
2679
2660
2700
2800
2900
3000
3100
3200
3300
3307
3600
3700
Gate
LANDING STRIP
Water Tank
36
31
2
3
5
6
7
8
10
11
12
13
14
15
17
18

MAP 14

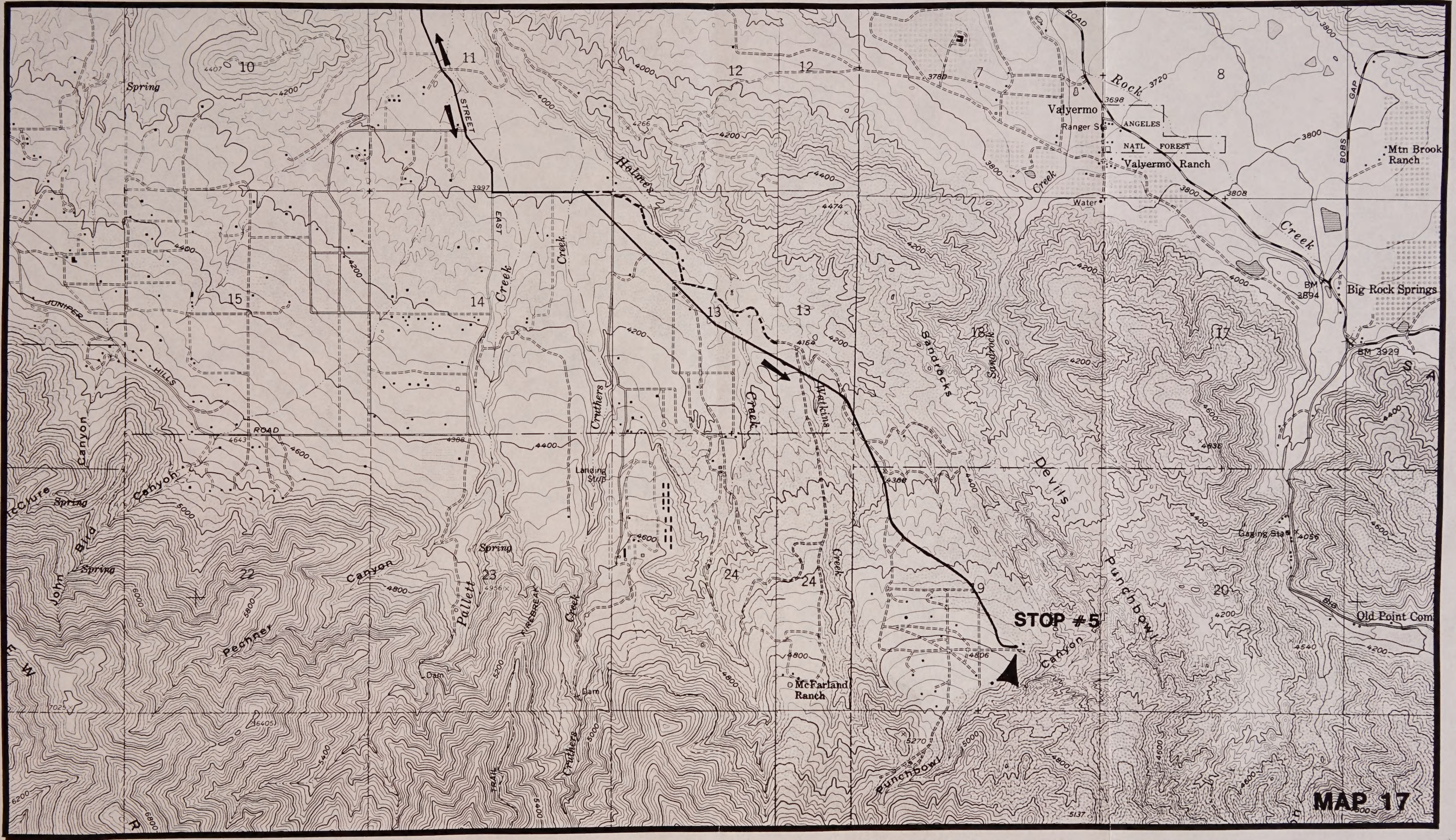

Four Points
WT
Trailer Park
Gravel Pit
Gravel Pit
Gravel Pit
Gravel Pit
Gravel Pit
AVENUE T
AVENUE T
AVENUE U
AVENUE V
PACIFIC
PEARBLOSSOM HIGHWAY
PEARBLOSSOM
HIGHWAY
57TH ST E
87TH STREET EAST
82D STREET EAST
96TH STREET EAST
106TH STREET EAST
Little Rock Wash
Little Rock
Trailer Park
Water Tank
Well
Well
Gas Tank
BM 2858
Cheseboro Siphon
CHESEBORO (OLD FORT TEJON ROAD)
CALIFORNIA AQUEDUCT
AQUEDUCT
Little Rock Siphon
Mile 355
Mile 356
Dam
LITTLE ROCK DITCH
CALIFORNIA DITCH
BM 2910
BM 2936
BM 2964
Littlerock
Gate
Little Rock
Carr Canyon
TUNNEL
Tunnel
FORT TEJON ROAD
138
ONE
9
10
11
11
12
7
8
16
15
14
14
13
18
17
21
22
23
23
24
19
20
2752
2765
2776
2749
2778
2799
2800
2803
2831
2843
2845
2847
2846
2850
2875
2893
2900
2937
2947
2950
2980
2946
3000
3009
3011
3030
3050
3070
3100
3150
3174
3134
3200
3357
3400
3492

MAP 15



EXIT AFTER LAST STOP TO PEARLBLOSSOM HWY. (STATE HWY 138

EXIT AFTER LAST STOP TO PEA


STOP #5
Valyermo
Ranger Sta
ANGELES
NATL FOREST
Valyermo Ranch
Water
Rock Creek
Big Rock Springs
BM 3894
BM 3929
Mtn Brook Ranch
BOBS GAP ROAD
Devils Punchbowl Canyon
Sandrocks
Gaging Sta
Old Point Com
McFarland Ranch
Punchbowl
Watkins Creek
Holmes Creek
Cruthers Creek
Pallett Creek
Spring
Landing Strip
EAST STREET
JUNIPER HILLS ROAD
John Bird Canyon
Canyon
McClure Spring
Pechner Canyon
FIREBREAK TRAIL
Dam
10
11
12
13
14
15
17
18
19
20
22
23
24
7
8

MAP 17